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MAYON VOLCANO AND ITS ERUPTIONS [1]

By LEOPOLDO A. FAUSTINO

Assistant Chief, Division of Geology and Mines
Bureau of Science, Manila

TWENTY-ONE PLATES AND THREE TEXT FIGURES

CONTENTS

INTRODUCTION

In the following pages it is proposed to describe Mayon Volcano and its immediate surroundings, to present more or less detailed descriptions of past eruptions and the eruption of 1928, and to give explanations of some of the phenomena observed. Strictly speaking Mayon is constantly in eruption, and the dates of eruption given here are to be taken to mean days of unusual or greater activity. The activity may be greater or less according to the frame of mind of the person or persons giving the reports. It is admitted that no two persons reporting on a volcano in eruption will find it in the same condition. However, there are cases where the accounts are a little exaggerated, as in the case of the last eruption. In order to satisfy the needs of a sensation-loving press some people sent in a few wild and highly-colored

[1] Submitted for publication November 15, 1928.

reports. The present report contains an account of the 1928 eruption based on the personal notes of the writer. The first trip to Mayon for the purpose of observing the 1928 eruption was made early in the year. In answer to insistent telegraphic requests of the Governor of Albay, Father Saderra Masó, assistant director of the Weather Bureau, and the writer left Manila for the Mayon area January 20, 1928. The period from January 21 to 24 was spent in making observations around the volcano. On account of the northeast monsoon and the accompanying heavy and protracted daily rains the crater of the volcano was visible only occasionally. It was noted, however, that the activity consisted of feeble emissions of vapors, mainly steam, from the crater. The vapors took the regular form of solfataric emanations, without any shape or form, apparently without any pressure from behind, and disappeared as soon as they reached a short distance above the summit. The people were told there was no immediate danger of a violent eruption, at least until May or June.

In response to a series of telegrams from the provincial authorities of Albay Province the writer left Manila June 26 to make observations on the reported activity of Mayon Volcano. Arriving in the Bicol region he found Mayon in mild eruption, throwing out dust and ashes. People were leaving their homes, and the general population was panicky. June 27, 28, and 29 were spent on the slopes of Mayon itself with Col. José de los Reyes, of the Philippine Constabulary. On July 1 the following report was handed the Provincial Governor.

THE GOVERNMENT OF THE PHIIPPINE ISLANDS
DEPARTMENT OF AGRICULTURE AND NATURAL RESOURCES
BUREAU OF SCIENCE
MANILA

LEGASPI, ALBAY, *July 1, 1928.*

Hon. MARIANO LOCSIN,
Provincial Governor,
Legaspi, Albay.

MY DEAR GOVERNOR: In compliance with your verbal request, I take pleasure in presenting herewith my observations on the present activity of Mayon Volcano.

1. Up to the present time the eruption has been a very mild one and has consisted merely in a quiet extrusion of lava from several places near the summit of the cone. The molten material issues from several notches on the sides of the crater and rolls down the slopes towards Libog in the form of rock streams and avalanches, red hot and incandescent, presenting fireworks display at night.

2. Unless conditions suddenly change, I see no cause for alarm and I see no reason why the people should not return to their homes.

3. Present indications are that the Mayon Volcano will continue in this more or less active state. The emission of smoke (dust-laden steam) and small lava flows may continue for some time and perhaps a little shower of volcanic dust may fall in the neighboring towns.

4. There is danger at the present time from the fragmental materials lying unstable on the slopes of the volcano, which with the coming rains may sweep down the mountain sides in torrential flood. The barrios of Arimbay and Bigaa of Legaspi and most of the barrios of Libog on the slopes should be warned.

Very truly yours,

LEOPOLDO A. FAUSTINO,
Assistant Chief, Division of Geology and Mines.

While the writer was preparing to return to Manila he sent the following telegram to the Director of the Weather Bureau:

LEGASPI, ALBAY, *July 2, 1928.*

FATHER SELGA, *Weather Bureau, Manila.*

No increased activity. Mayon continues mild eruption. Constant emission of grayish white smoke (dust-laden steam). Occassional small lava flows from the crater. Present conditions indicate prolonged activity without danger. Returning to-day Bicol Express.

FAUSTINO.

Subsequent developments sustained both reports. The climax of the present activity was probably reached July 19 and 20, and the week following. July 22 the writer was again in the Mayon area, this time in company with Father Selga, director of the Weather Bureau, and Vicente del Rosario, chief of the Executive Bureau, who representing Governor-General Stimson, was chief of the relief work. July 24 Father Selga and the writer, while making observations on the slopes of the volcano in company with W. L. Bowler, of Legaspi, had the experience of being enveloped by a dark heavy ash-cloud without suffering any ill effects.

During the latter part of August Father Selga revisited the Mayon area to collect more specimens of the volcanic products and to obtain temperature measurements. At that time it was noted that the volcano was returning to its normal state of mere emission of steam vapors.

Grateful acknowledgment is here made of the many courtesies extended by the provincial authorities and inhabitants of Albay during the course of the investigation, and in the preparation of this report the writer wishes to record his apprecia-

Based on Coast and Geodetic Survey Map — MAYON VOLCANO AND NEIGHBORING TOWNS ALBAY PROVINCE — Made in the Division of Geology & Mines, Bureau of Science.

FIG. 1. Mayon Volcano and the neighboring towns in Albay Province.

tion of the help and encouragement given by Father Selga and Father Saderra Masó of the Weather Bureau and Director Brown and the scientific personnel of the Bureau of Science.

GEOGRAPHY

Mayon Volcano is situated in the extreme southeastern part of Luzon, in Albay Province in latitude 13° 16′ north and longitude 123° 41′ east. From Manila it may be reached via the Manila

Railroad in less than twenty-four hours. Rising from a broad base on the western shores of Albay Gulf between the towns of Legaspi and Tabaco it forms a remarkably symmetrical mountain and has rightfully earned the name of the "most perfect cone in the world." The summit terminates in a small crater 2,421 meters above sea level according to determinations by the United States Coast and Geodetic Survey.[2] This volcano has been described by Abella (1) as *una inmensa tienda de campaña cónica* (an immense conical tent). The more or less circular base may be said to have a radius of about 10 kilometers. On the periphery of this base are located the most important towns of Albay Province; namely, Tabaco and Malilipot on the northeast, Libog on the east, Legaspi and Daraga on the southeast, Camalig on the south, and Guinobatan and Ligao on the southwest. In addition there are several barrios and settlements on the slopes of the volcano, and some people from Masarawag, a barrio of Guinobatan have built camps almost halfway to the summit.

According to the 1918 census the number of people living in the immediate vicinity of Mayon Volcano is 178,794. This estimate

[2] This is the figure given on all United States Coast and Geodetic charts since 1910. In answer to our request regarding the present height of the Mayon on account of the last eruption, the Director of Coast Surveys was good enough to furnish the following information:

"The published height of 2,421 meters was determined for geographic and navigation purposes only. While it is, perhaps, safe to say that this height is correct to within 10 or 15 meters, it is undoubtedly not of sufficient accuracy to compare with a more accurate determination, if made at the present time for the purpose of noting any change of height due to the recent disturbances.

"It is difficult to secure accurate observations for elevation in the Islands because of the excessive refraction. This refraction can be determined only by means of reciprocal observations. To secure these would necessitate ascending Mount Mayon with a theodolite and awaiting for favorable observing conditions. Unfortunately the hydrographic work of the *Fathomer* will not permit of the delay which would be necessary to secure this information."—L. O. Colbert, lieut-commander, C. and G. S. Director of Coast Surveys.

It is certain that the height of Mayon Volcano has changed from time to time, perhaps more after each eruption. The differences in the following determinations, however, are due more to the methods used rather than to the elevation itself. In 1859 Jagor's own barometric reading was 2,374 meters. According to Abella and Coronas the Spanish Hydrographic Commission gives 2,522 meters, the determination having been made sometime before 1870. In 1881 Abella gives the height of Mayon as 2,734 meters, while d'Almonte's map of 1883 gives 2,527 meters.

includes all the inhabitants of the region within a radius of 15 kilometers, and is distributed as follows:

TABLE 1.—*Population of towns in the vicinity of Mayon Volcano.*

Town.	Population.
Bacacay	20,211
Camalig	19,772
Daraga	([a])
Guinobatan	25,113
Legaspi	52,756
Ligao	21,467
Libog	7,391
Malilipot	7,272
Tabaco	24,812
Total	178,794

[a] Included in Legaspi. The name of the municipality of Albay has been changed to Legaspi by Act No. 3253 of the Philippine Legislature, approved December 3, 1925.

"Act No. 3253.—An Act changing the name of the municipality of Albay, in the Province of Albay, to Legaspi, and for other purposes.

"Be it enacted by the Senate and House of Representatives of the Philippines in Legislature assembled and by the authority of the same:

"Section 1. The name of the municipality of Albay, capital of the province of the same name, is hereby changed to Legaspi: *Provided, however,* That all provincial and municipal government offices and their dependencies shall continue in the former municipality of Albay.

"Section 2. This Act shall take effect on its approval.

"Approved, December 3, 1925."

These towns are connected with each other by first-class roads, and the Ammen Transportation Company maintains a fleet of autobuses which run on regular schedule. The first-class road of the province runs around the volcano and at a point called Sabloyon, midway between Tabaco and Ligao, the provincial authorities have constructed an observation platform, from which an imposing view of the volcano can be had at close range (about 6 kilometers) across a deep ravine. The Manila Railroad winds around the southern and eastern slopes and terminates in Tabaco. During the last eruption, upon being assured that there was no immediate danger, the enterprising manager of the Legaspi Division of the Manila Railroad, Domingo Onrubia, ran excursion trains at night to view the fireworks of the volcano.

From the surrounding towns the land rises gradually, at times going down in a broad depression, at other times rising abruptly to form small hills. These small hills are cinder cones of low elevation. A number of these hills merit attention. To the northeast and, in a way shielding the town of Malilipot from the fury of Mayon, is a line of two or three prominences running

northwest and southeast or almost parallel to the long axis of Tabaco Bay. The most northern of these prominences is the highest and has an elevation of 457 meters. This range of hills is called Tancolao and extends southwest of barrio San Antonio of the municipal district of Tabaco, where it ends in an abrupt cliff. At the foot of the cliff is the provincial road from Tabaco to Ligao. To the north of Legaspi is a more conical hill called Liñgion, which rises to an elevation of 169 meters.

Aside from these minor undulations near the base, which do not materially affect the sine curve of the slope, Mayon rises like a symmetrical cone and the slopes present the same pleasing curve from whatever direction it is viewed. At first the rise of the land is scarcely perceptible, then there is a gradual increase in the angle of the slope, and as the summit is approached the fragmental product of previous eruptions assumes the angle of repose varying from 35 to 45°. Mayon Volcano is not only the most beautiful of all the volcanoes in this region but is the highest, and can be seen from steamers approaching San Bernardino Strait and also from Burias and Ticao Islands and farther.

The flanks have ravines radiating from the summit, those on the eastern slopes are more marked than those on the other sides. Toward the base of the mountain some of these ravines have a depth of 50 meters and a width of as much as 30 meters. Near the summit they are not so deep and appear more like grooves when seen from the neighboring towns. However, when viewed farther away the scars disappear and the perfect symmetry of the cone becomes impressive. Even the outline of the summit, which is being gradually roughened by weathering and erosion, seems to taper almost to a point.

There is no beaten trail to the summit. Sometimes the route leads through one of these ravines, at other times on a hogback between two ravines. On account of the slope and the loose material consisting of cinders, scoriæ, and lapilli lying upon a somewhat harder base of volcanic material the last 500 or 300 meters of climb is beset with difficulties. A rope and a good climbing stick are indespensable. Tennis shoes and native *alpargatas* are more reliable than heavy boots or hob-nailed shoes.

The summit of Mayon was reached many times even during the Spanish occupation. Huerta(8) writes that in 1592 a Franciscan friar, Reverend Pedro Ferrer, attempted to climb the mountain to dispel the superstitions of the natives regarding the

volcano. He did not reached the top, but he brought down a sample of sulphur, which was probably the first sulphur discovered in the Philippine Islands. In the same year another Franciscan friar, Reverend Estevan Solis, accompanied by a lone guide made a similar attempt but was prevented from reaching the summit by three *bocas* (mouths or depressions). According to Jagor(9) two young Scotchmen, Paton and Stewart by name, were the first ones to reach the top, although in "Trabajos y Hechos Notables de la Soc. Econom. de los Amigos del Pais," for September 4, 1823, it is said that "Don Antonio Sigüenza paid a visit to the volcano of Albay on the 11th of March, and that the Society ordered a medal to be struck in commemoration of the event, and in honor of the aforesaid Sigüenza and his companions." In 1859 Jagor himself made the ascent.

In 1876 von Drasche(7) reached the summit, and his description of the summit with a sketch was published two years later. It is generally known that a number of Spaniards and Filipinos have made the ascent from time to time although no records have been made of the trips as the ascent was considered as a not particularly dangerous feat. Since the American regime a number of expeditions have been recorded. In 1902 a party of Americans ascended the crater and took many photograps. In 1911 Bishop McDonald of Legaspi and party reached the summit and his photographs of the crater are shown in this report. In 1922 a party from Legaspi consisting of some thirty persons made the ascent. Carlos Stillanopulos, one of the members of the party, described the trip as follows:

> We started early in the afternoon and managed to reach close to the end of vegetation before nightfall. There we camped and had our dinner. We were well stocked with provisions, and it was a merry crowd, singing and making all kinds of noises. Leaving our base camp early the next morning we reached the rim of the crater a little before noon and after taking a number of pictures of the party started back for the base camp. Some of the members reached Legaspi that night but most of the party remained at camp and returned to town the next morning. It was not particularly a dangerous climb but required careful foot work and a good eye for small boulders which might be turned loose in one's direction. Near the crater we found the skeleton of a human being, which some of the members of the party thought might be the guide of some Americans who ascended the Mayon in 1920 and who was lost in the typhoon but who was thought to have returned later.

The United States Army fliers were able to take some good photographs of the summit during the early days of the 1928

activity. Arriving late in the afternoon of June 29 two Army fliers from Camp Nichols, near Manila, circled the volcano at an altitude of about 2,500 meters. According to Lieut. George W. Goddard on account of the heavy mantle of cumulus clouds he steered nearer the summit than he intended and came within 200 meters of the crater before he knew his position. He says that he felt the heat very strongly and inhaled a quanity of sulphur gases. Lieutenant Goddard estimated the diameter of the crater to be about half a kilometer.

He described it as apparently almost circular, with perpendicular walls, and a deposit of cindery material on the sides, and a pool of bubbling hot lava in the center. On account of the escaping gases and steam vapors it was difficult to make detailed observations of action in the crater.

The following notes regarding the crater are based on observations and photographs of those who had made a trip to the crater of Mayon during the interval between the 1900 and 1928 eruptions. All descriptions agree that the crater rim is notched at several places, but the main chute is on the eastern side in the direction of Libog. This main chute seems to divide the crater into a north and a south rim. Those who have stood on the rim or on some of the projecting rock promontories estimate the diameter of the crater between 300 meters and 500 meters with a more or less ragged edge made by immense bowlders standing on one side as if ready to fall at a moment's notice. It appears that the highest part of the rim is toward the west and southwest or in the direction of Ligao. Several persons had descended into the bottom of the crater and had taken good pictures of the pit. Several of which appear in this report. The bottom of the pit is estimated to be bewteen 50 and 100 meters below the crater rim. It consists in part of an apparently thick layer of heavy subangular bowlders between which are emitted steam vapors and other gases, in part of smaller particles, granulated fragments, and sand, and in part of small pools of alkaline waters, highly heated and vaporizing. These volcanic emanations sometimes assume such proportions as to appear like a characteristic "panache" of volcanic mountains. At the bottom of the crater some of the rock materials are covered with incrustations which may be true volcanic sublimates. Volcanic sublimates are generally deposited by or from volcanic gases. Among the numerous incrustations generally encountered among volcanic vents, only two have so far been identified in the crater of

Mayon. A small sample brought by Mr. Wiley, of the Manila Railroad Company, and which he says was taken from between two rock masses on the walls of the crater proved to be aluminium sulphate. According to A. D. Alvir, geologist of the division of mines, Bureau of Science, the white earthy mineral has all the properties of alunogen, which may be formed by acid solutions acting upon aluminous rocks. The sample tastes like alum. The most conspicuous of the volcanic sublimation products in the Mayon crater is native sulphur, where it occurs around numerous vents both on the floor and on the sides.

The walls inside the crater are perpendicular and consist of large blocks, lapilli, some scoria, and volcanic sand in intimate mixture with occasional wavy lines indicating structure. It appears that the irregular stratification is the result of successive deposits and flows during past eruptions. At the base of the perpendicular walls are talus deposits varying in size according to recency of formation, the more recently formed reaching higher on the walls. No dikes are apparent on the walls, although lines of loose rocks simulating dike structure run irregularly from the rim to the base of the crater.

The view from the summit of Mayon stirs the imagination, and many a climber has remarked it is well worth the hardship of the climb. Land and sea, fields and forests, villages and towns with their churches and government buildings stretch out in diminutive form as far as the eye can see. Parties generally plan to reach the crater during early morning or, at the very latest, at noon, as then the summit is uncovered and no clouds obstruct the view. Even then the solfataric vents give off enough steam vapors to make the surrounding air hazy.

CLIMATE AND VEGETATION

In order to understand better the effects of Mayon eruptions it is necessary to give a few salient features of the climate of the Bicol region, particularly with regard to rainfall and wind direction. On account of its latitude and position with reference to the Pacific, the Mayon area has rainfall throughout the year, with a minimum in April and May and a maximum in November and December. Given a rich volcanic soil with rainfall throughout the year it is not to be wondered that the plains of Albay are ever green with vegetation. Sometimes, however, the condensation of moisture reaches serious proportions and

water falling on the slopes of the volcano flows in torrents first in the ravines and then across the lowlands carrying everything in its path in its rush to the sea. Floods of this nature are particularly dangerous in view of the fact that as a result of previous eruptions fragmental materials, incoherent and merely lying in unstable equilibrium on the slope, are ready without a moment's notice to come down, made mobile by the onrushing waters.

There are on record at least two great disasters caused by typhoons in which the rainfall on the slopes assumed great proportions and caused volcanic materials to roll down to the plains and on to the sea after the manner of mud flows, only with more mobility and with greater rapidity. Huge bowlders of volcanic rock, 5 or 6 meters in diameter, resting on volcanic sand can be moved with sheets of water 5 to 10 centimeters deep by carrying away the sand particles underneath and disturbing the equilibrium. Once the blocks on the slopes start moving there is no stopping until the low depressions are reached or the materials are deposited in Albay Gulf. The first great disaster of this kind on record was in October, 1766, when it is estimated that thousands of people perished and much property was destroyed. About one hundred years later, in November, 1875, another flood caused heavy destruction and the number of victims is estimated at 1,500 saying nothing, of course, of the money value of the property damaged. In both of these disasters the path of the waters was one of desolation, a mere expanse of bowlders and sand with pieces of wood and branches of twigs to mark the place where once was a field, a garden, or a thriving community.

In 1915 a stream flood again occurred and brought down bowlders of varying sizes, sand and gravel, and other materials, which covered the tracks of the Manila Railroad between Legaspi and Libog and also the provincial road. For more than two weeks communication between the two towns was suspended. Similar floods have occurred from time to time, and they have caused considerable damage to crops and to other agricultural products. Many more destructive floods have occurred than are recorded, and some of the people have devised ways and means to minimize destruction. Some plantation owners of Camalig struck the novel idea of building dams, which protected their property to some extent but diverted the water to some other property so the destruction was no less.

Table 2 shows the monthly average of rainfall in Legaspi at the foot of the volcano for sixteen years.

TABLE 2.—*Monthly average of rainfall at Legaspi, Albay.*

[Census of the Philippine Islands for 1918 1 (1920) 345.]

Month.	mm.
January	376.3
February	273.2
March	171.5
April	126.4
May	133.6
June	207.3
July	230.7
August	172.5
September	251.7
October	328.8
November	348.8
December	488.5

In the consideration of the effects of eruption the direction of the wind is also important, as the wind is the medium by which the volcanic sand, ash, and dust thrown into the air are carried to near-by and distant places. The fate of the barrio or community is determined in part by the direction of the wind and its permanence in that azimuth. In the following table of wind directions it can readily be seen that the prevailing wind during the first six months is northeast and east northeast while that during the last six months is southwest and west southwest. These wind directions are those observed near the surface.

TABLE 3.—*Monthly percentages of wind directions at Legaspi, 1903–1908.*

[From the Philippine Weather Bureau.]

Direction.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
N, NNE	30	25	22	18	11	6	3	1	4	13	27	32
NE, ENE	51	50	52	50	36	25	9	5	8	27	41	49
E, ESE	7	10	16	17	15	11	4	5	5	7	8	6
SE, SSE	-----	-----	-----	1	1	1	1	1	1	1	1	0
S, SSW	-----	-----	-----	1	3	6	7	6	7	4	1	0
SW, WSW	-----	-----	-----	1	5	13	35	46	35	12	3	1
W, WNW	-----	-----	-----	-----	2	4	10	14	10	5	2	1
NW, NNW	1	-----	-----	-----	1	1	1	1	2	1	1	1
Calm	11	14	9	12	28	33	31	23	28	29	16	10

At higher levels of the atmosphere, however, the air sometimes takes a different direction of movement, and very fine

materials thrown into the air and reaching the height of 10 kilometers or over may not be blown in the direction of the wind recorded at the surface of the land. Oftentimes the direction of air movements at higher levels is unknown, but sometimes it can be observed. Table 4, taken from a Weather Bureau report, will show that there is a difference in the direction of air movement at higher and lower levels of the atmosphere.

TABLE 4.—*Form and direction of cloud observed at Legaspi station, Albay, July, 1920.*

[Explanation of symbols: Ci, cirrus; Ci-S cirro-stratus. A-Cu, alto-cumulus; Cu, cumulus; N, nimbus; Fr-N, fracto-nimbus; Cu-N, cumulo-nimbus.]

Day.	6 a. m.			2 p. m.		
	Amount 0–10.	Upper.	Lower.	Amount 0–10.	Upper.	Lower.
1	9	Ci-S	Cu-N WSW	7	Ci-S	Cu-N WSW.
2	4	Ci	Cu	2	Ci	Cu SSW.
3	7	Ci	Cu	5	Ci-S	Cu SSW.
4	9	Ci-S	N ENE	8	Ci-S	Cu-N ENE.
5	8	Ci-S	Cu NE	8	Ci-S	Cu-N ENE.
6	8	Ci-S	Cu SW	7	Ci-S	Cu SW.
7	8	Ci-S	N WSW	9	Ci-S	Cu WSW.
8	5	Ci-S	Cu SW	10	Ci-S	Cu-N WSW.
9	10	Ci-S	N	10	Ci-S	N WSW.
10	10	Ci-S	Fr-N WSW	10	Ci-S	N W.
11	10	Ci-S	N W	10	Ci-S	N W.
12	10	Ci-S	Fr-N WSW	10	Ci-S	Fr-N WSW.
13	10	Ci-S	Fr-N WSW	10	Ci-S	Fr-N WSW.
14	10	Ci-S	Fr-Cu WSW	7	Ci	Cu WSW.
15	5	A-Cu WSW	Cu WSW	5	Ci	Cu WSW.
16	10	Ci-S	Cu WSW	9	Ci-S	Fr-Cu WSW.
17	9	Ci-S	Cu-N WSW	6	Ci-S	Cu WSW.
18	7	A-Cu WSW	Cu WSW	10	Ci-S	Cu-N WSW.
19	10	Ci-S	N WSW	10	Ci-S	Fr-N WSW.
20	10	Ci-S	Fr-N WSW	10	Ci-S	Fr-N WSW.
21	10	Ci-S	N WSW	10	Ci-S	Fr-N WSW.
22	10	Ci-S	Fr-N WSW	8	Ci-S	Cu WSW.
23	6	A-Cu ESE	Cu WSW	8	Ci NNE	Cu WSW.
24	2	C	Cu WSW	3	Ci	Cu WSW.
25	5	Ci	Cu WSW	7	Ci	Fr-Cu WSW.
26	10	Ci-S	Fr-Cu WSW	10	Ci-S	N WSW.
27	10	Ci-S	N WSW	10	Ci-S	N WSW.
28	10	Ci-S	N WSW	10	Ci-S	N WSW.
29	8	Ci-S	Cu WSW	7	A-Cu	Cu WSW.
30	6	Ci	Cu WSW	3	Ci	Cu WSW.
31	6	Ci-S	N WSW	7	Ci E	Cu-N WSW.
Mean	8.1			7.9		

Mayon's eruptions have had no small effect on the vegetation on its slopes. As a matter of fact the present vegetation shows in no small degree the sphere of previous eruptions. The northern and western slopes are covered with vegetation almost to the summit, while the southern and particularly the eastern slopes are practically barren except for a few isolated spots of grasses and small trees. On the northern and western slopes there are forest trees with trunks ranging from 10 to 50 centimeters in diameter, heavily covered with air plants and without the usual entanglement of climbing vines. Apparently no heavy flows of lava and incandescent materials have taken this direction for a very long period, although it is evident from the nature of the ground that during the previous eruptions some of the materials thrown into the air have fallen and have run down the northern and western slopes. During the 1928 eruption small streams of rock materials thrown in the direction of Guinobatan reached the 1,000-meter elevation, and descended following the ravines. Toward Masarawag the forest belt stops at an elevation of 1,000 meters, abacá plantations and isolated patches of coco and other trees cover the rest of the slope down to the base. On the broad base of Mayon Volcano the dominant crop is abacá with a sprinkling of coco palms. These plantations, however, give way to a scanty vegetation on the southern and eastern slopes particularly those places in the direction of the streams of sand and big bowlders. At an elevation of 300 meters cogon and other grasses predominate. As a matter of fact the lower slopes of Mayon Volcano may be described as covered with triangular areas of cogon and other grasses with the apex of the triangles reaching the higher portions and between which are areas of barren volcanic ejecta. A small irregular belt of stunted trees occurs on the eastern slopes at a 600-meter elevation directly in front of the main lava flow of the 1928 eruption. Upward beyond the cogon belt is a scanty vegetation of small grasses and shrubs with patches of raspberries. The last 500 meters to the summit is practically barren, nothing but sand and bowlders lying at the angle of rest, and sliding downward at every opportunity.

GEOLOGY

Mayon Volcano is a cinder cone, whose form is determined by the angle of repose of fragmental materials, mostly ash, lapilli, and volcanic ejecta, which have been thrown into the air during

eruptions and have fallen at or near the crater or exuded through the notches on the sides of the crater. These materials pile up around a restricted orifice. Anything in excess of the angle of repose rolls down the slopes to rest at a lower elevation or at a lower angle of slope. As a result the slope is very steep near the summit but descends gradually into the lowlands at the base. In other words there is a very gradual rise from the plains to an elevation of about 500 meters or within a 6-kilometer radius from the crater. The vertical outline of the volcano assumes the hyperbolic sine curve, which Becker [3] was able to represent by a mathematical formula.

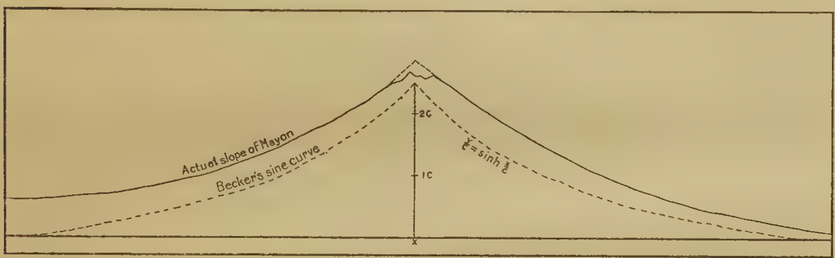

FIG. 2. Form of cinder cones.

It appears from Becker's discussion of the formula that the form assumed is dependent upon the resistance of the material to crushing. During each eruption materials ejected into the air and falling at or near the summit as well as those flowing from the crater are distributed evenly on the slope so that the vertical depth of the added material is practically the same from the summit to the base. Becker (5) explains that "of course, more material falls near the top than near the bottom, but more rolls down from the steeper slopes of higher portions than from the gentler slopes near the foot."

It is generally agreed that the framework of Mayon Volcano consists of layers of lava flows and fragmental materials ejected from a restricted orifice. Surface manifestations point to only one volcanic conduit, although Abella (1) spoke of numerous fissures and subordinate openings, which, according to him, were not preserved on account of the steepness of the slope and the incoherent character of the materials. During the 1928 eruption Father Selga and the writer watched particularly for signs of

[3] 18th Ann. Rept. U. S. Geol. Survey, pt. III (1898) 20–25.

subordinate openings but none appeared. If there have been subordinate openings or parasitic cones on the slopes they have not left any evidence of their existence and present indications are that has been only one opening.

Along the ravines and gullies on the upper slopes some stratification of materials was observed. The external structure on these higher slopes consists of layers of fragmental materials and consolidated ash. The ash has hardened to a relatively firm continuous mass varying in thickness from 10 to 50 centimeters. These beds can be readily recognized in some of the photographs.

The materials found on the slopes are the same as those found on any other volcano, large angular masses of solidified lava, sometimes partly fused, agglomerates, scoriæ and cinders of varying sizes and shapes, and volcanic sand. The lava from this volcano has been the subject of investigation by a number of workers. It was described by Roth and von Drasche(7) as dolerite, by Oebbeke as olivinitic augite-andesite, and by Abella(1) as essentially basalt with feldspar and augite as the predominating minerals. The Mayon area was mapped by Adams and Pratt(2) as basalts with andesites. A. D. Alvir, geologist in the division of mines, Bureau of Science, examined a number of thin sections of rocks from previous eruptions and from the 1928 eruption. His notes follow:

> Apparently Mayon has been erupting the same types of lavas as shown by the remarkable uniformity in the mineral composition of the samples taken for examination. The lavas of previous eruptions are andesitic basalt with calcic plagioclase (labradorite) predominating. The texture is andesitic, automorphic porphyritic with a glassy hemotitic mesostasis containing microcrystals of feldspar and hypersthene. The automorphic phenocrysts are labradorite (a few andesine) and augite. Most of the augite and a few of the feldspar phenocrysts have their edges resorbed. The majority of the feldspar, however, have peripheral and zonal growths which are clear of inclusions while the minerals within the former boundaries have inclusions. The other accessory minerals are magnetite and hematite. A sample of lava from the present eruption collected by the Constabulary detachment shows the same automorphic porphyritic texture and the same abundance of augite and labradorite feldspars. The groundmass is glassy, slightly cryptocrystalline, and dark.

It cannot be definitely stated just when Mayon Volcano first appeared, but it is reasonably certain that it is one of the youngest, if not the youngest, of the line of volcanoes in the Bicol region. It would seem that the original vent was made during the closing period of the Tertiary or early Quaternary by rifting

through tertiary sediments. The volcanics and eruptives of this region are known to be younger than the Tertiary formation. The rise has been gradual but more rapid than the ravages of erosion and new extruded materials filled up the ravines and gullies formed, so that the repeated activity was able to keep the external form from disfigurement. Each eruption has added more materials to the cone and has gone toward perfect symmetry and form, and the ejected materials have served to smooth over the irregularities caused by erosion and weathering.

PREVIOUS ERUPTIONS OF MAYON [4]

Mayon Volcano is the most active cone in the Philippines. It has had periodic eruptions during the last three hundred years and it may be considered to be in normal state when volcanic vapors, sometimes dust-laden, appear at the summit. The earliest record of Mayon in eruption was made about 1616 by Spilbergen, although no details were given regarding the intensity or destruction. During the following hundred or more years accounts of voyagers from Mexico approaching San Bernardino sometimes record the existence of a volcanic mountain in the distance emitting "smoke."

The first eruption to be described at length was July 20, 1766, and lasted six days. It is said that a column of "fire" rose from the crater and a current of lava descended the eastern slope. According to the records of the Franciscan fathers Mayon continued its mild activity until 1800, when greater activity was shown. Large amounts of stones, sand, and ashes were thrown out causing much damage to the towns of Cagsaua, Budiao, and others, including some cultivated fields. During the last of October of that year the action was more violent and more destruction was caused to the towns.

February 1, 1814, the most violent and destructive eruption of Mayon occurred. It was preceded by local earthquakes the day before, continuous during the night, and culminating in a violent eruption at 8 o'clock in the morning. Following a strong quake, a huge column of dust-laden steam vapors rose from the crater, and darkened the whole surroundings. To add to the terrifying scene volcanic lightning flashed back and forth. A torrent of "fire, lava and large hot stones" rolled down the southern slope, destroying everything in its path. The towns

[4] Based on reports of Aragon, Abella, Coronas, Masó, and others.

of Camalig, Cagsaua, and Budiao and half of Albay and Guinobatan were laid in ruins, and according to records 1,200 people were killed.

During the years following, Mayon emitted volcanic vapors in greater or less quantities. In June, 1827, there began a period of activity which lasted until the beginning of the following year. In 1834 small flows of incandescent lava from the crater were noted. This activity was maintained until May, 1835, and there were times when bombs and ashes were thrown into the air but fell not far from the crater. Noises similar to loud thunder were heard. On January 21, 1845, subterranean noises were again heard followed by a small eruption of ashes at the crater lasting ten minutes. This was followed by another eruption and still another at intervals of fifteen and thirty minutes, respectively. An ash cloud appeared at the top of the volcano and was blown by a northeast wind, and ashes fell on Camalig and Guinobatan. During the week following there could be heard in the daytime sounds that were described as great multitudes of rocks striking against each other and at night as of a distant waterfall. A similar eruption occurred the following year, 1846, and in 1851 there were two other small eruptions of ashes.

On July 13, 1853, an eruption occurred which lasted only a few hours but which caused considerable damage to life and property. This eruption was preceded by loud subterranean noises, without local earthquakes, followed by an extrusion of an immense column of dust, treelike and spreading at the top. Incandescent rocks rolled from the summit on the slopes to the base of the volcano destroying many houses and causing the death of thirty-three persons. Although the eruption lasted only one afternoon all the towns at the base of the volcano were covered with ashes.

March, 1855, there was another small eruption. During the year 1858 there was considerable activity consisting of quiet flows of lava and incandescent materials on the sides of the volcano with emissions of small quantities of ashes at the crater. From 1861 to 1868 there were frequent outbursts of ashes and dust, but none assumed dangerous proportions. At times during this period there could be seen a glow at the summit. December 17, 1868, dust-laden clouds, low and spreading, appeared at the summit, and some ashes fell.

December 8, 1871, there occurred an eruption that caused the death of three persons. Early in the morning loud subterranean noises were heard, and between 7 and 8 a. m. three particularly strong ones, after which an immense column of dust-laden cloud rose majestically and then spread to shower ashes and dust on all the neighboring towns. The northeast wind carried the ashes toward Camalig and Guinobatan, and at both places it was so dark that the people had to use lamps. There were mud balls the size of bullets or smaller. From the crater molten lava and incandescent rocks rolled down the sides. At 10 a. m. it cleared somewhat, and it was found that a deposit of ashes 4 millimeters in thickness had covered the fields, roofs of houses, and other places. At 1 p. m. there was a similar explosive eruption with lightning and thunder. In the evening the whole mountain could be seen illuminated with the lines of red-hot rock streams running in the direction of Legaspi. The waters in the streams became turbid on account of the suspended ash materials. In the "visita" of Bocton, or Bogton, two persons were suffocated and in Buyuan, or Buyuhan, one was burned.

In September, 1872, there was an eruption which lasted four days. There was emission of ashes and lava, and subterranean rumblings. The following year, 1873, a similar eruption occurred, this time with more vigor and activity, and lasted from the middle of June to July 22, with the climax June 20.

July 6, 1881, began a period of prolonged activity which lasted until the middle of the following year. In spite of the heavy rains the evening of July 6, 1881, the people of Tabaco noticed a glow at the summit of the volcano which was due to a reflection of molten lava and incandescent materials. July 16 incandescent rocks were seen rolling down the slopes following the ravines and barrancos. The activity was repeated at 11 p. m. of July 22 with distant rumbling sounds. Mayon continued more or less active during the months following. At 11.30 a. m. November 21 heavy dark clouds appeared at the summit and ashes began to fall, while greater quantities of incoherent and fragmental rock materials more or less incandescent descended the slopes. Their lines of descent were marked by white vapors and gases emanating from the materials. Shortly after 12 noon there was heard a deafening noise, and at 2 p. m. the whole mountain was covered with dark ash-clouds. In the towns to the south and southwest the air was heavy and sultry. With the

east wind blowing most of the ashes in the air fell on Camalig and Guinobatan. The phenomenon was repeated with similar manifestations, December 14. There followed a gradual decrease in the activity. From November 21 to the first days in December, particularly November 23 and 24 and December 2, there were tranquil emissions of molten lava and fragmental materials from the crater along the barrancos toward the south, and a little to the east and west of south, which reached 400 to 600 meters below the summit. The dust-cloud accompanying the eruption November 24 assumed the imposing height of 600 meters. None of the reports mentioned showers of ashes, and subterranean noises and rumblings were noted only a few times.

Again in 1886 and 1887 another eruption of long duration occurred beginning in July and ending in March. The activity July 8, 1886, and February 22 and 27 and March 1 and 9, 1887, was more violent. There was constant emission of ashes forming into dust-clouds and falling on the neighboring towns of Camalig and Guinobatan, sometimes so darkening the atmosphere as to require artificial lighting for a few hours. Red-hot rocks rolled down the slopes almost constantly, and on one occasion the whole summit appeared to be on fire. The deposit of ash in Guinobatan reached a thickness of 3 millimeters. December 15, 1888, there were two eruptions of ashes accompanied by roarings and rumblings. September 10, 1890, small flows of incandescent material were noted on the eastern slopes. Toward the end of the month the activity was more violent with a considerable amount of ashes thrown to immense heights, and flows of molten materials and incandescent rocks reaching almost the base near the town of Libog. The following year, 1891, from October 3 to 18 there were eruptions of ashes and much molten material was extruded.

The eruption in 1892 lasting from February 3 to 29 was described as having been preceded by light earthquakes the year before, and consisted of explosive ejections of ashes, lapilli, and bombs from the crater with electric lightnings, subterranean roarings and rumblings, and flows of incandescent rock materials from the crater. It was one in which greater activity was shown, and many inhabitants in fear left the towns of Libog and Camalig. According to reports, during January it was noted that the quantity of ash-clouds was greater than in the usual emissions. February 3 a glow was seen at the summit. In the evening of February 9 small flows of lava were seen

trickling down the slopes, and on the 21st the activity was in full blast with great quantities of ash-clouds, and incandescent materials rolling down the eastern slopes. On the 24th emissions of ashes were made every fifteen or twenty minutes and explosive ejections of bombs and lapilli could be seen clearly from the lowlands. The ejections of volcanic materials continued on the 25th and 26th, and at 10 p. m. the 26th a huge column of dust-laden vapor rose from the crater and electric discharges darted back and forth. The activity with the accompanying roarings and rumblings continued through the 27th and the 28th, but after the 29th the activity grew more or less quiet. It is reported that the cone lost 100 meters during this eruption.

The following year, 1893, another eruption occurred lasting from October 3 to 23. This eruption exhibited the same manifestations as one the year before—emissions of ashes, lapilli, and bombs with accompanying roarings and rumblings, and again molten materials descended the eastern slope. An important event of this eruption was the tremor, fairly strong and of long duration, felt October 11 and October 18. During July and August, 1895, there were slight eruptions. Indistinct roarings and rumblings were heard, and some materials were ejected from the crater but fell back into it, and the flows of incandescent materials on the slopes were slight. The following year, 1896, in August and September slight eruptions occurred with similar manifestations as the ones in the previous years.

The most destructive eruption of Mayon since 1814 occurred June 25 and 26, 1897. The premonitory signs were definite and pointed clearly to an impending disaster. May 13, 1897, a strong earthquake was felt in the region of Albay and neighboring provinces and from the data presented in Table 5 it may be inferred that the movement was along a seismotectonic line extending from Guimaras Strait through Masbate, northwest of Samar, and San Bernardino Strait. The Monthly Bulletin of the Weather Bureau for October, 1897, shows that this earthquake was recorded in Europe. Father Sederra Masó doubts if this earthquake can be related to the eruption of June, citing the fact that many strong earthquakes have occurred in the neighborhood of Masbate at different times without showing any relation either to the activity of Mayon or to that of any other volcano in the vicinity. It is possible, however, that earth movements of a tectonic character may provide passages for the flow of molten lavas.

TABLE 5.—*Terremoto de 13 de Mayo de 1897* [a]

Estación.	Hora.	Clase de movimiento.	Intensidad escala I–VI.	Dirección.	Duración.	Observaciones.
Albay.......	7h 44m p. m.	De rotación y oscilación.	IV	N.–S.	30s	Empezó con movimientos rotatorios, siguiéndose después las oscilaciones.
Tabaco......	7h 45mm p. m.	De oscilación.	III	N.–S.	30s	Crugían las maderas; las puertas se movían mucho.
Masbate....	7h xm (minutos ántes de las 8.)	De oscilación y trepidación.	VI	......	......	Este terremoto llenó de pánico a los habitantes de Masbate. La circunstancia de ser allí de madera casi todos los edificios hizo que los desperfectos no fueran de consideración, evitándose así las desgracias personales. La iglesia parroquial de la Cabecera, el pantalán y algún otro edificio sufrieron las naturales consecuencias del fenómeno (I). Aunque no se precisa la duración de éste, dícese, con todo, que afortunadamente no fué mucha.
Calbayog....	Cerca de las 8 p. m.	De oscilación.	III	......	30s	
Cápiz	Xh (entre 7 y 8 p. m.)	....id....	III	E. O.	25s	
Calivo (N. de Panay)..	.....id.........	....id....	II	......	......	
Iloílo	.....id.........	....id....	I	......	......	

[a] La erupción del volcán Mayón en los días 25 y 26 de junio de 1897. Manila Observatorio (1898) 55 pp.

It cannot be definitely stated that the earthquake of May 13, 1897, had any relation with the eruption of June, 1897. However, Coronas(6) records that immediately following the earthquakes of May 13 it was noted that dust-laden vapors began to appear at the crater and small quantities of lava and molten materials began to descend the eastern slopes in the direction of Libog. During the remaining days of May the glow at the crater was clearly visible at times and there were subterranean noises. Slight earthquakes were felt May 22 and 27 and June 1, 2, and 4. After the tremors of June 4 the glow at the crater remained

visible at all times and June 21 there were heard unusual noises, forerunners of impending disaster. June 22, 23, and 24, emissions of ashes and molten materials kept increasing in quantities, the while subterranean roarings and rumblings were heard incessantly. June 24 found Camalig enveloped in a cloud of ash, which darkened the whole town. The most violent phase of the activity began in the afternoon of June 25 and lasted for seventeen hours. Not only were there huge columns of dust-laden vapors emanating from the crater, and great quantities of molten lava, incandescent rock materials flowing in all the barrancos in the direction of Libog, but volcanic bombs and lapilli were being thrown into the air and were falling on the slopes amidst flashes of electric lightning zigzaging in all directions. The incandescent rock materials following the depressions and the drainage lines swept everything before them and did not stop until they had reached the shores of Albay Gulf. Barrios of Libog were completely overwhelmed—San Isidro, San Antonio, Santo Niño, San Roque, and Misericordia, and part of San Fernando, also the barrio Bigaa of Legaspi. A ridge in front of Libog serving as a wedge divided the flow of the volcanic materials into north and south branches, thus saving the convent and the town hall and the school of Libog from the effects of the volcanic flow. It was reported that ashes fell within a radius of about 80 kilometers although the amounts varied in different places. At Tabaco the deposit had reached a depth of 50 centimeters in twenty-four hours, while at Tiwi it was 15 or 20 centimeters, and at Virac, Catanduanes Island, it was 6 centimeters. At Legaspi and Daraga the fall of ashes was 1 or 2 millimeters or less. Small lapilli were reported to have fallen in Camalig and Ligao. The explosions of this eruption and the subterranean rumblings were heard at great distances. Reports from Tayabas and Camarines Norte tell of distant noises heard in those places June 25 and 26 even before it was known in Manila that Mayon was in eruption. Reliable estimates place the number of victims of this eruption between 200 and 300. Most of the deaths seemed to have been caused by hot blasts and from the rolling incandescent materials.

Mayon was again in eruption March 1, 1900, but the activity was less violent. Red-hot rock streams flowed from the summit and there was constant roaring and rumbling. It was reported that all the houses in Ligaspi were shaken, and doors and windows rattled during the explosions. The column of dust-laden

clouds rose to the imposing height of about 8 kilometers, and when the materials fell there was slight darkness. A small quantitiy of ashes fell in the neighboring towns.

The foregoing brief review of the eruption of Mayon about which we have any written record reveals many interesting features. The sections which have always been the scenes of destruction are the east and south, while the north and west have suffered very slightly. Most of the deaths have occurred on the slopes and at the base within a radius of 10 kilometers from the crater. The eruptions have been characterized in the main by explosive ejections of ashes, sometimes in great quantities, previous to outpourings of lava from the crater.

ERUPTION OF 1928

From 1900 to 1928, a period of twenty-eight years, Mayon Volcano remained apparently inactive, at least steam vapors were not noticed emanating from the crater. Agents of erosion had deepened somewhat the barrancos, the crater had become a little disfigured, and materials from the sides had begun to accumulate at the bottom. It was the longest rest period Mayon had had during the last one hundred fourteen years of its eruption history. The rest was so long that Chester A. Reeds writing in Natural History for May-June, 1928, remarked that "in all probability the next eruption will be exceptionally violent."

The 1928 activity of Mayon Volcano may be said to have begun some time in January. Persistent reports of underground roaring and rumbling reached Manila from Legaspi. There were conflicting reports regarding "smoke" from the crater. At the instance of the Provincial Governor of Albay, Father Saderra Masó, assistant director of the Weather Bureau, and the writer went to Legaspi for study and investigation. The party spent one week in the vicinity of the volcano but, on account of the bad weather conditions, was able to make observations only two days. It was noted that there was a feeble emission of steam from the crater, scarcely visible except with strong field glasses, without any pressure from behind, and the vapors disappeared as soon as they reached a short distance above the summit. Reports from ex-Governor Betts and other residents of Legaspi state that this feeble emission of water vapor continued, with more or less interruption, during the following months. Finally, about June 16, the emission of vapors assumed greater propor-

tions and in the evening of that day residents of Libog claimed to have seen a glow at the summit of the volcano.

The following week was filled with confusing and inconsistent reports. While press correspondents at Legaspi were filling the Manila newspapers with reports of "subterranean noises and huge columns of smoke from Mayon," other people were sending in news of no smoke and no eruption. It was difficult to judge the state of activity from the telegraphic dispatches from Legaspi. This state of affairs was brought to a head June 24, when clouds of condensed steam rose from the crater, apparently dust-laden, and hung over the summit, showing that Mayon was once more entering into a period of activity. From that time there was no longer any doubt as to the activity of Mayon, and throughout the Philippine Islands reports from Legaspi were anxiously awaited.

The writer left Manila at noon June 26, and reaching Pamploma, Camarines Sur, early in the morning of June 27, saw Mayon with an unmistakable pinnacle of eruption clouds silhouetted against the horizon. The vicinity of the volcano was reached about noon, but rain clouds had enveloped the upper half of Mayon and it was impossible to make out what was transpiring behind the screen. A trip was made around the volcano in an attempt to discover some premonitory signs of a destructive volcanic eruption. With the exception of faint explosive reports, scarcely audible even in the more or less deserted town of Libog, nothing was observed that might have indicated an approaching destructive eruption.

Toward evening, as the sun was disappearing behind the western horizon and darkness setting in, the crater became cleared of all obstructions and a volume of steam could be seen emanating from it, forming a "cauliflower" structure some distance above. The clouds immediately above the crater were pale crimson, due to the reflection of the glowing lava within the crater.

At exactly 6.40 p. m., June 27, 1928, the first incandescent material was seen rolling down the eastern slope in the direction of Libog, at first small and tearlike, but gradually increasing both in size and in recurrence. The view at kilometer 9 on the Legaspi-Libog road was imposing and awe-inspiring. There was the famous Mayon silhouetted against the clear sky, showing the curve of its slope, the symmetry of which has been the subject of universal comment. At the summit was the small

crater filled with bubbling lava. Clouds of condensed steam hung above, lighted by the glow of the molten material. Occasional bursting of the bubbles caused fragments of material to be shot into the air. The reports of the explosions which blew out the lava could be distinctly heard. The materials ejected were of all shapes and sizes (some pieces probably weighed hundreds of kilograms), but only a few fell outside the crater. As activity within the crater increased the bubbling lava boiled like a viscous liquid and began to pour out through the notches on the sides of the crater, at first following the ravines and gullies, forming snakelike trickles radiating from the summit. The molten material crusted over and cracked, and as glowing-hot rocks hit against each other smaller pieces of incandescent material were broken off and shot into the air—all of which, with the lines of red-hot rock streams, formed a spectacular pyrotechnic display.

The activity increased during the night, though not to an alarming point. The incandescent materials descended first about 300 meters below the crater, then 200 meters lower, and continued to push their way lower and lower until finally, at about 4 a. m., June 28, 1928, the molten rock had reached a point about 1,000 meters below the summit. Toward daylight the spectacular display apparently ceased, as the incandescence could no longer be seen; but the steam and vapors emanating from the crater and the sides and along the paths of the incandescent material bore direct evidence of continued activity.

Throughout Thursday, June 28, 1928, reports of explosions within the crater were clearly but faintly heard at irregular intervals. Condensed clouds of steam together with other clouds hung over the summit and presented a threatening aspect. Late in the afternoon an unusual outburst of fine material (volcanic dust and sand) filled the otherwise white clouds, turning them black. As these black clouds swept down the sides of the volcano some 300 meters below the summit in the direction of the barrio of Bigaa, Legaspi, the inhabitants of the district were seized with a panic. Men, women, and children seeking safety, ran pell-mell, carrying what little belongings they could gather together on the spur of the moment, driving before them in all directions the domestic animals filling the air with shrieks and howls—a veritable pandemonium.

Two unusually deep ravines from the summit met about 1,000 meters below the crater in a large hollow which began to fill with molten material; the glowing rocks remained incandescent for

some time. Toward evening sufficient material had accumulated in the depression to give it the appearance of a subordinate crater. Streams of red-hot rocks continued to roll down the eastern slopes forming in their advance a tumble of igneous bowlders which, upon addition of more material, slowly crept toward the lowlands. July 1, 1928, the front had reached more than 1,200 meters below the summit. The outflow of incandescent material continued with more or less regularity, although on certain days, notably July 5 and 6, comparatively small amounts were observed.

Mayon continued to belch forth vapors and gases, which hung over the summit in clouds. An official report from the Philippine Constabulary, dated July 9, 1928, tells of heavy black "smoke" from the crater July 8. This was of course due to the very fine material (volcanic dust and sand) which was being blown into the condensed clouds of white steam. Explosions within the crater were said to be louder though they occurred at longer intervals. Apparently Mayon had entered into another period of more violent activity. There were several explosive eruptions Sunday, July 8—namely, at 10 a. m., 5 p. m., 10 p. m., and 11.30 p. m. During these eruptions there were violent extrusions of fragmental materials of various sizes into the air, and roaring and rumbling, and incandescent materials rolling down the slopes. The eruption at midnight was accompanied with brilliant fireworks display, and the black clouds formed umbrellalike silhouettes. There were times between explosions, as was the case at 6 p. m., when the crater showed no emission of vapors.

The activity subsided somewhat during the week following. There were less rumbling and the flow of incandescent materials was slight. Apparently it was only a preparatory period. July 16 a telegram from Governor Locsin to the Weather Bureau stated that volcanic materials had begun to descend toward the northeastern slopes and that there were violent extrusions of fragmental materials from the crater between 11 and 12 p. m. The people in the neighborhood began to notice that the roaring, rumbling, and hissing noises, loud cracking, tumbling, colliding, and apparent unloading of heavy rock materials took place every three or four hours, sometimes five hours, and that the occurrence was periodic though not necessarily rhythmic. The most violent phase of the activity had begun. The culmination was reached July 20. At intervals the previous day, heavy columns of dark vapors surged straight into the sky. The activity increased somewhat July 20 and in the evening there was a spectacular

display of incandescent materials, bombs and lapilli describing parabolic curves from the summit, a column of heavy dark clouds above, the top of Mayon fire red, streams of red-hot rock materials flowing apparently in all directions. There was an incessant flashing of brilliant lightning from dust-cloud to dust-cloud and from the crater in all directions. It was an imposing sight and terrifying. The people were in a state of nervous fear.

The violent activity continued until July 23. There were periodic manifestations of imposing columns of dust-laden vapors moving spirally and towering above the surrounding regions. At times, when the wind did not make possible the towering columns, "the volcano appeared like a gigantic locomotive puffing on a heavy grade." One of the best examples of these huge columns of gas and ash rolling upwards after a fashion from a constricted orifice was observed at 6 p. m. Sunday, July 22.

In order to review the mechanism of the emission of these huge columns of dust-laden vapors a party consisting of Father Selga, director of the Weather Bureau; W. L. Bowler, of Legaspi, and the writer decided to camp near the front the lava flow and watch for an emission. The emissions had been occurring at intervals of four and five hours, and at 9 a. m. July 23 we were rewarded with one of the largest displays of the volcanic ejections of ashes. The emission was constant; steam vapors with their load of ash rolling upward in succession of circular rings moving clockwise gave the appearance of a ropy structure to the whole column. The column was fearfully black and the circular rings were apparently of the same size until high up in the column they began to spread umbrellalike. These imposing columns had been estimated at various times and by various persons, but probably the most reliable determination was the one made by officers of the United States Coast and Geodetic Survey Ship *Fathomer*, which was working in Lagonoy Gulf. They determined the height of the column on July 20 as 8 kilometers from the summit of the cone. After the energy pushing the column upward was exhausted, the materials in the clouds began to drop, and a heavy curtain of dust and ashes hung around us and darkened the atmosphere. The west wind blew the mantle in the direction of Libog, Bacacay, and Malilipot and in less than an hour we were out of darkness and ready for another observation.

These periodic emissions of dust and ashes had caused showers of fine materials within a radius of 40 kilometers, as far as the town of Virac, in Catanduanes Island. The fall was not particularly heavy, but the materials that had fallen July 19 and 20

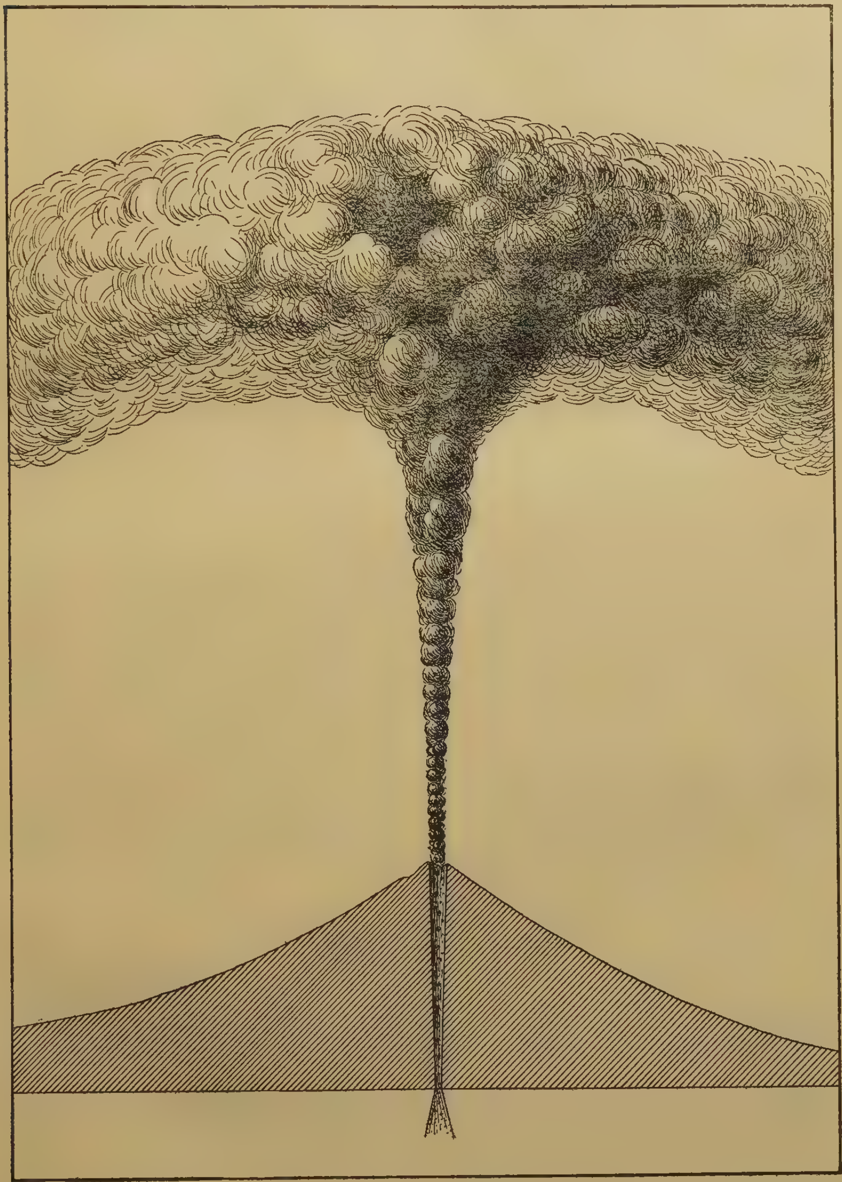

FIG. 3. Sketch drawn to scale showing the relation between the cone of Mayon and the towering column of eruption clouds spreading at the top during one of the periodic outbursts. (Modified after Perret.)

and the days following damaged the green vegetation on the southern and southeastern slopes of the volcano. Leaves of the abacá plants, between Daraga and Camalig in particular, wilted and turned brown, later with black spots. Acacia, santol, and pilli trees lost most of their leaves, the cogon and other grasses on the slopes including bamboos turned burnt-brown. The damaged area extended in a belt about 7 kilometers wide starting a little south of Guinobatan and swinging around the base of the volcano through Camalig and Daraga and portions of Legaspi across the barrios of Bigaa and Rawis of Legaspi to Libog, Malilipot, and Bacaycay. A great number of trees and bamboos in Camalig, Daraga, and in the barrio of Bigaa, Legaspi, had the portions facing west and away from the volcano brown and wilted; the portions facing the volcano were green and apparently unharmed. The selection of portions damaged was due to the direction of the wind.

The flows of molten lava from the crater and the rock materials which were sometimes half-fused, incoherent, and fragmentary followed at first two or three distinct ravines and barrancos, but after these were filled and had built up they formed ridges and the former ridges or hogsbacks became the depressions. After the main depressions were filled, the flows from the summit became more or less general, all, however, taking the direction of Libog or a little to the north and south. The different lines of descent were well marked during the day by dust clouds following the incandescent or half-fused materials shooting downward on the slopes, and at night by the glow and glitter of red-hot rocks. The following is a description by Dr. H. W. Wade, director of the Culion Leper Colony, who with W. L. Bowler, of Legaspi, and Frank W. Sherman spent July 27 and 31, 1928, on the slopes of Mayon Volcano for observation of certain features of the eruption:

Because they are heaped considerably higher than the general level of the ground beside them, it is not at first evident, at least in some cases, that these ridges follow the course of small ravines running fairly directly down the side of the mountain. It could be thought that they are meandering down on fairly level ground, as it could be thought that a ship resting on quiet water is flat-bottomed. Actually, the pile has a keel. so to speak, that fills a small ravine.

To the novice these ridges seem merely piles of rock and rock fragments. It is difficult to realize at first that they are, in effect, rock glaciers. Standing beside one of lesser activity, it might be supposed that the occasional slide of small material that rattles down the side of the rock

ridge, and the rolling down of a massive bowlder, is due solely to the tendency of heaped-up loose material to attain a stable slope-angle, for the angle of the sides is usually 45° or greater. But if the effect of falls at a given point be watched long enough it is realized that the slope does not become less, that the place left by such falls is gradually taken up, that the falling is due to the forcing outward of material by pressure within. This pressure, obviously, can come only from far above, where the mountain slope is greater and where new material is constantly being added.

Unavoidably, the falling down of material at the sides of the ridges tends to broaden them out, but in the main this seems to be very slow. Ground countours and the accumulation of larger rock masses at the base of the sides may tend to inhibit broadening. However, it seems probable that the main factor is that, due to the character of the material, most of the force is transmitted along the axis of the slide, and that weight of the mass tends to overcome the lateral pressure. In other words, there is a tendency to establish a lateral equilibrium, so to speak. When this is approached falling at the sides becomes less and less frequent, though at the end of the slide it is still more or less active and the slide as a whole continues to progress downward.

Such was the case with the ridge, a lateral stream somewhat out of the line of direction of the main flow, beside which our party camped on our first night on the mountain. When we first reached it the mass, towering sharply some 50 feet above us on the same ground-level, and correspondingly farther up the hill, was very impressive. Every few minutes, somewhere along its length, a mass rolled down the side, sometimes reaching the bottom entire, sometimes smashing into fragments. In either case, though it was full daylight, red was usually seen somewhere, either in the falling mass itself or in the place from which it came, and often along the course of its fall. Once in a while a momentary flicker was seen, as if of a bit of flame, but from prolonged observation at night, when so much red is seen that nearly every fall is something of a spectacle, the writer is very doubtful that there is any real flame; a splash of powdered fragments of the red-hot material may cause the illusion of flame.

It is not to be understood that there is no flame in connection with these slides. It is easily seen at night from the road below. But this is due to red-hot material setting fire to the grass and other vegetation along the sides of the slides.

At first the party did not seriously consider spending the night beside the slide, with a difficult crossing to be made to get onto the safe side of the ravine in case of need. But as the hours passed and the slowness of change was realized, and after exploration of the ground-contours under the 10-foot elephant grass uphill from us, it was decided that it was safe to stay there, where the night spectacle of the slide beside us would be so much more impressive than from the lower ground across the ravine. The decision was fully justified by the course of events. No one of the party would have missed the experience, in spite of the fact that camp was moved at about 2 a. m. This was done because, during and after an hour's noisy blow-off by the mountain, the flow on the upper slope in-

creased greatly, and with sense of perspective impaired by the darkness the party came to fear that escape might be cut off by filling of the ravine to be crossed. Four days later there was no very great change at this point on the mountain. The slide had not widened materially; the camp site was about as far from being covered as when we first reached it.

But though this ridge was but slightly active, comparatively, its lower end did progress, and at the second visit it was probably not less than 100 yards farther down than at first. On the first visit a series of photographs was taken of the end, to illustrate the mode of progress. Two rather large heads of rock stood out at the moment, these evidently in rather precarious equilibrium. At brief intervals material fell, sometimes a flow of fine stuff, sometimes rocks, as the one that stirred up the dust. In the few minutes that the flow was watched from this vantagepoint, the nearer of the two heads fell, or at least lost its top, with a roar of falling stuff and a dense cloud of dust. Close comparison of the knobs shows that the mass rotated as it fell; the picture was taken as it was going over. The mass of dust and sandlike material seen shooting up was due to the fall of rocks the dislodgement of which caused the upper mass to fall.

The dust that arises with every fall of rock is one of the interesting features, at least to one who is within range of it. Looking at the rock slides from Legaspi, or from the road at the foot of the mountain, it looks like smoke, and many think it to be that. In places where movement is most active, as in the tremendous pile, which moved downward, we believe, at least a half kilometer during our second night on the mountain, the illusion of a smoking, burning pile is perfect. However, though the rock mass is red-hot a foot or so under the surface, there is no sign of any such emanation from it when there is no disturbance of the surface by falling material, though some may arise in a strong gust of wind. Neither by sight nor smell was the writer able to convince himself that there is any smoke in it; certainly it is mainly, and I believe it to be solely, powdered burnt rock. The odor, it was said by a member of the party, is similar to that arising in a foundry when molten metal is poured into sand molds.

The dust is by no means impalpable. Carried by the wind it gets into everything. One's eyes are full of it, one's teeth grit with it; it gets into the works of one's camera and one suspects its presence within one's watch. For the skin it seems to have an abiding affinity!

The writer believes that much of the "smoke" given off from the crater during a period of eruption (a "blow-off") is of the same nature. Certainly it must contain more or less of it. On several occasions during eruptions we heard a sound as of rain falling sharply on the grass about us, caused by showers of coarse particles. However, the emanation from the crater is probably not a single material. During some eruptions voluminous, dark clouds are given off, but on other occasions it is much less voluminous, so far as the eye can determine, and pale. On one occasion we were showered, apparently from the crater, with impalpably fine material that fell in particles that splashed on landing, as do heavy wet snowflakes. Nothing just like this was seen about the slides.

Samples of rock material from the 1928 eruption were analyzed by Gil O. Opiana, assistant chemist, Bureau of Science.

TABLE 6.—*Analysis of material from the 1928 eruption.*

	Per cent.
Silica (SiO_2)	50.25
Alumina (Al_2O_3)	18.95
Ferric iron (Fe_2O_3)	4.90
Ferrous iron (FeO)	4.19
Phosphorus pentoxide (P_2O_5)	0.34
Titanium oxide (TiO_2)	0.89
Manganous oxide (MnO)	0.14
Lime (CaO)	9.60
Magnesia (MgO)	4.00
Potash (K_2O)	1.38
Soda (No_2O)	5.19
Chlorine	0.06

From the analysis it may be noted that the silica content is about 50 per cent, hence the rock may be properly termed basic. Had the rock been the only extrusive material from the volcano and had it escaped from the crater as a fluent, smooth, ropy lava of the pahoehoe type, being highly basic and very mobile, it would have spread to a great distance before solidifying, and a Mayon with more or less flat slopes would have resulted. The flow of molten material from the summit of the volcano has been a subject of frequent discussion, particularly among those who witnessed the last eruption.

Von Drasche(7) writing on Mayon concluded that small lava flows had been erupted from the summit. Abella(1) maintained that great amounts of lava, although fragmentary and incoherent, flowed almost constantly during periods of activity. Coronas(6) in his report on the eruption of 1897 included several figures of that and of previous eruptions in which the supposed path of lava flows from the summit of the volcano was outlined in red. Adams and Pratt(2) in their reconnaisance of southeastern Luzon expressed the opinion that probably molten lava issued only from near the summit and seldom descended more than one-third of the slope before cooling.

The writer was at the volcano at the beginning of the 1928 eruption and made observations during the course of the eruption, and, knowing the different opinions regarding this phenomena, directed particular attention to this point. There is an element of truth in all the foregoing statements. As has been remarked the main framework of Mayon Volcano consists of layers of lava flows and fragmental materials. During periods of activity several kinds of materials are extruded, principally half-fused materials from the crater walls and molten lava. There were times when fluid lava could clearly be seen flowing from the main chute

in small intermittent streams. The molten lava cools very quickly and, after passing through the steep descent, piles up and generally takes the form of the cindery scoriaceous, or the *aa* type of lava. There were times when the emission consisted largely of solid angular blocks, and half-fused materials, and very little or no molten lava.

August 1, the main stream of these rock materials had forked at a 600-meter elevation into a northeast branch and a southeast branch. The tumble of rock materials at the front had every appearance of a terminal moraine in glacial regions. The loose materials, some half-fused and incandescent, some scoriaceous and cindery, incoherent and rugged in outline, were lying at the angle of repose in a ridgelike formation toward the lowlands. Secondary transitory fumaroles developed on these lava streams, and, according to Father Selga's records, some attained a temperature of 320° C. These materials advanced, following ravines and gorges, and kept on their journey to the lowlands during the months following. In October and November these igneous bowlders of varying sizes and shapes covered portions of the railroad tracks and the provincial road between Legaspi and Libog. On the western slopes the lines of rock streams had reached to about 1,000 meters elevation, although they were mere rivulets compared to the main flows.

The emission of gases and dust from the crater continued during the first half of August but with decreasing violence and display. The roaring and rumbling gradually disappeared and the lines of glowing rocks at night became less and less distinct so that by the end of August the present eruption may be considered to have terminated. Aside from the streams of rock materials in the direction of Libog, and the barren slopes, and the somewhat different shape of the crater, nothing in the neighborhood bears evidence of an eruption. The trees and plants damaged in July have recovered and once more the plains and slopes of Mayon are covered with green vegetation. The people have returned to their homes, and the disturbance which caused no little commotion and mobilized all the government forces and the Philippine Chapter of the Red Cross has settled down—to wait for the next eruption.

CHARACTER OF MAYON'S ERUPTIONS

During the one hundred fourteen years of Mayon's history following the destructive eruption of 1814 we have a record of at least twenty-eight distinct eruptions, an average of one eruption every four years. The longest periods of apparent inac-

tivity were from 1900 to 1928, a period of twenty-eight years, and from 1814 to 1827, a period of thirteen years. From 1885 to 1900, fifteen years, Mayon was more or less constantly in eruption except in the years 1889, 1894, 1898, and 1899. It is apparent that the normal state of Mayon is one of continuous mild activity, and that the long periods of rest followed the most violent eruptions. The thirteen years following the eruption of 1814 was the second longest period of inactivity, and the years following 1897 with the exception of a small eruption in 1900 were marked with no activity. This may be explained by the fact that after a period of violent activity it must take a longer time for replenishing of stock and resumption of activities. The shape and form of the cone of Mayon bear mute evidence that its eruptions have never been violent enough to cause destruction to the form, and that the volcanic conduit has always been in the center. Most of the eruptions have been merely to patch up incisions made by agents of erosion.

In the discussion of the premonitory symptoms of Mayon's violent eruptions, which caused much destruction to life and property, the eruptions of 1814 and 1897 are taken as basis. The violent eruption of February 1, 1814, was preceded by local earthquakes the day before, which were continuous during the night. The violent eruption of June 25 and 26, 1897, was preceded by strong earthquakes in Albay and the neighboring provinces, and continuous local earthquakes were felt May 22 and 27, and June 1, 2, and 4. On June 22, 23, and 24 subterranean roaring and rumbling, which might be compared to artillery discharge underground, kept increasing in intensity and violence as the crisis was approached. According to one resident of Libog the springs which supplied their drinking water failed previous to the violent explosion. Both eruptions were marked with violent activity in the emission of gases and dust from the crater. The extrusion of immense columns of dust is the most constant of these premonitory symptoms. The eruption of July 13, 1853, lasted only one afternoon but caused the death of thirty-three persons. This violent eruption was preceded by loud subterranean noises without local earthquakes, followed by the sudden emission of gas and ash and incandescent materials so suddenly that the people on the slopes were caught unawares.

Von Drasche(7) in defining the characters of the eruptions of Mayon adopted Stohr's hypothesis of three periods in the life history of a volcano as follows: First, lava flows;

second, agglomerate flows; and third, eruptions of ash. According to this life history von Drasche believes that Mayon is in the second stage, though Abella(1) strongly opposed this opinion. The writer agrees with Becker(5) that there could hardly be such regularity in the life history of a volcano, and that while some volcanoes may have followed the succession of events as implied in the hypothesis there are others which have not shown any indication of regularity. It must be remembered that Stohr's hypothesis refers to the different stages of the life history of a volcano and not to the different phases of an eruption period. For a classification of these different phases of a volcanic eruption, Perret in his description of the Great Eruption of Vesuvius in 1906[5] divided them into the luminous, liquid-lava phase; the intermediate, gas phase; and the dark, ash phase. The luminous, liquid-lava phase refers to the glow of the molten materials in the crater at the beginning of new activity, while the dark, ash phase refers to the culminating stage of the eruption. In the case of Mayon the luminous, liquid-lava phase is of short duration, the intermediate gas phase, characterized by vapors and gases with but little ash, is longer. The dark, ash phase is characterized by the preponderance of ejected, ash material.

It is well known that the immediate cause of volcanic eruptions is the explosive force of pent-up steam and that the gases are the chief eruptive elements. The supply of these gases has been assumed to be at some unknown depths and the source is the magma itself or the surrounding materials of the lithosphere, the wall rocks.[6] The periodic and irregular evolutions of gas at the upper extremity of the volcanic conduit which result in spasmodic activity may be assigned to the manner in which the gases reach the topmost lava inside the crater. Even if the supply of gases from the sources were uniform there would be a difference in the amount reaching the top of the volcanic conduit on account of the irregularities in the process of transmission and diffusion. During periods of repose the topmost lava solidifies, and the gases accumulate beneath. As soon as the gases acquire sufficient energy, they explode their way through and dust clouds result.

The topmost lava being thus blown into fine dust and ash, the lavas from the deeper parts of the column come up and

[5] Carnegie Institution Pub. No. 339 (1924).

[6] Iddings, J. P., The Problem of Volcanism, Yale University Press (1914) 246–555.

these materiales are exuded through the notches on the sides of the crater. The microscopic study of these lavas shows that they are rich in augite phenocrysts. In the study of lavas from Vesuvius [7] it was found that the "rapidly-moving" lavas, of the *aa* type, are rich in augite phenocrysts, and that they "were derived from the deeper parts of the column and were composed of magma that issued highly charged with gas, hence highly mobile and capable of rapid and distant flow and complete crystallization in spite of the continuous movement." The Mayon lavas do not show complete crystallization, but the size of the crystals bears evidence, that they came from below the upper part of the column. At times small outlets are maintained and the supply of gases is likewise small and more or less uniform so that a "panache" of dust cloud is maintained for some time. The evolution of volatile gases sufficient to triturate the volcanic materials into the fine dust be tremendous, particularly so when the amount and character of the trituration of the materials and the height to which they are blown are considered. A sample of dust from the 1928 eruption collected at Libog by the detachment of the Philippine Constabulary has been separated according to sizes with the following result: Particles less than 0.589 millimeter in diameter, 78 per cent; more than 0.589 and less than 1.168 millimeters, 13 per cent; more than 1.168 millimeters, 9 per cent. Other samples collected are similar showing that a great percentage of the dust is fine material, and in order to account for the manifestation of dust-laden steam rising to 8 kilometers it is necessary to assume a very considerable length of the bore.

The volcanic dust of Mayon settling upon the surrounding country did some damage to the vegetation. The damaged areas were more in the south than in the north and northeast, although the direction of the wind was from the west and southwest. This is explained not only by the fact that the dust and ashes assumed the form of a funnel with the greatest diameter above when extruded violently from a restricted orifice, but that the winds at higher levels blew in the opposite direction. The ashes and dust upon being carried to the west and southwest were then taken up by the winds nearer the surface and deposited on the leaves of plants on the southern and eastern parts of the area. In the region about Camalig and Daraga in particular the

[7] The Vesuvius Eruption of 1906, Carnegie Institution of Washington (July, 1924) 146.

parts of some plants facing the volcano were green and undamaged, but the parts away from the volcano and facing the southwest were brown and wilted. Inhabitants of the damaged areas were not in any particular agreement whether the falling ashes were hot or fairly hot. Some claimed they were hot enough to be noticed, others did not notice any heat. The fact remains that following the big eruptions of ashes, July 20 and later dates, there were intermittent showers, and the leaves of plants turned brown and wilted. In cases where the entire leaf was not damaged they were spotted where the dust had fallen and settled down.

Samples of dust and ash were collected in the different parts of the Mayon area, particularly in those districts where damage to the plants was greatest. Portions of these samples were put on the leaves of the same species of plants damaged in Camalig and Daraga growing on the Bureau of Science grounds and vicinity under similar conditions of sunshine and rainfall. The plants were not damaged in any way. Father Selga performed the same experiment with the plants in the vicinity of the Weather Bureau with the same result. Portions of the same samples were given to the division of general, inorganic, and physical chemistry, Bureau of Science, for chemical analysis. Preliminary report showed the dust to be neutral with litmus. The final report, however, showed the material to be decidedly acid, although it could not be expected to give an acid reaction except at high temperatures.

The chemical analysis made by Gil O. Opiana, assistant chemist, Bureau of Science, of the dust collected is shown in Table 7.

TABLE 7.—*Analysis of dust from Mayon Volcano.*

	Per cent.
Silica (SiO_2)	49.11
Alumina (Al_2O_3)	21.30
Ferric oxide (Fe_2O_3)	6.12
Ferrous oxide (FeO)	2.31
Phosphorus pentoxide (P_2O_5)	0.33
Manganous oxide (MnO)	0.15
Titanium oxide (TiO_2)	0.53
Lime (CaO)	9.65
Magnesia (MgO)	3.64
Potash (K_2O)	1.14
Soda (Na_2O)	4.37
H_2O+	0.64
H_2O-	0.36

There is a detectable amount of Cl and SO_4; NO_3 is absent.

The phenomena may be explained as follows. Hydrochloric acid gas is one of the common products of volcanic eruptions, and the presence of chlorine in detectable amount, as shown by the analysis, shows that it is not wanting in the Mayon exhalation. The volcanic dust provided a nucleus for the condensation of moisture present in the air. Hydrochloric acid gas has a very strong affinity for water and is at once absorbed, so that when the dust settled on the leaves of plants it carried a solution of hydrochloric acid which caused the damage. Hydrochloric acid, however, evaporates quickly and samples taken from Mayon and brought to Manila would not give the same effect. It will be recalled that the damage to the plants in the Mayon area was temporary.

On the slopes of the volcano in the ravines and on the stream beds and on the tops of rocks the deposit of dust and ash was, of course, much thicker and in some places attained an average of 20 millimeters. During the day the front of the rapidly advancing material from the summit shooting down the ravines and gullies was marked by trailing dust-clouds. At night the glow of the incandescent materials and the occasional bursting of the fragments, simulating flames, marked the lines of descent. At times a bluish flame was observed in front and over the surface of the lava flow which might have been true volcanic flames due to the presence of inflammable hydrogen and hydrocarbons. Loud roaring accompanied by hissing noises from the moving lava flow are due to the escaping gases. The molten lava, half-fused materials, and other ejectamenta moving very rapidly on the first descent, then settling down to a clinkery flow first filled the ravines and gullies and at the end formed a tumble of rock materials simulating a glacial moraine. Upon leaving the crater the molten lava began to solidify and behaved as regular *aa* lava, advancing by overriding the already solidified portions and presenting a brittle semisolid front, irregular blocks falling from the fiery mass beneath. At the beginning of each outburst the topmost lava is shot upward as finely divided ejecta by powerful gaseous expansion. A sufficiently high temperature is maintained by chemical action to make a pasty mass extrude through the notches on the sides. This boiling over after each ash eruption is peculiarly characteristic of Mayon. During the evolution of gases and the sudden extrusion of materials, other semifused materials on the bottom and sides of the crater may be thrown, and there may be the accessory ejecta which describe parabolic curves from the summit.

In other words, the extruded materials from the crater may be molten lava, half-fused materials, solid lava, or fragmental ejecta.

The so-called cyclical interval of repose and renewal of volcanoes was well exhibited by Mayon during its last eruption. It appears that a succession of potentially explosive magma rises through the volcanic conduit, and whenever the gas accumulation has reached a maximum saturation the disturbance of the equilibrium is sufficient cause for an outburst and an eruption. There is then released energy and material which have been accumulating during a period of lesser activity, although during these periods there is temporary relief through minor outbreaks. After each outburst there follows a period of rest, which may be due to exhaustion of the supply or obstruction of the conduit or diversion of the column. A fresh supply of explosive materials from the unknown source rises and begins to accumulate beneath the topmost lava to repeat the cycle. At the beginning of each cycle the explosive magma appears to pulse in surges of increasing violence, and seems to be bent on producing dynamic paroxysms.

At 600 meters elevation the advance of the lava flow, which has been referred to as the slide, moved rather slowly. The bottom of the flow appeared to have solidified and the movement was by the half-fused, half-solidified materials overriding the solidified lobes below. At this point the rate of movement was estimated at half a kilometer every twelve hours. The slower movement was due to the lower angle of the sine curve of the slope and to the not overplentiful supply of fresh materials from the summit. September 1 the vanguard of the flow was at 500 meters elevation and was taking possession of the deep ravines and gullies. Of course, the manner of movement had changed to a mere yielding to gravitation as a result of overaccumulation.

Observations of the nature of the emission of the volcanic ejecta and accounts of the people who survived the 1897 catastrophe, indicate that most of the deaths due to Mayon eruptions are caused by falling and rolling hot rocks, and by superheated and suffocating gases emanating from the lava. It is claimed that so much gas comes from rolling incandescent material that there is no escape for a person overtaken; many persons lost their lives because they were unable to dodge the advancing gases, which have been termed *lawi lawi* by the Bicolanos. Deaths are apparently instantaneous as sometimes the victims

are found in their customary positions. Some of the bodies were charred beyond recognition.

During the present eruption of Mayon there were persistent reports that Bulusan Volcano, a neighboring volcano in Sorsogon, situated in the same belt was also emitting ash and dust. The sympathetic action between the two sister volcanoes is not proved this time as Bulusan has been emitting a little ash and dust constantly. During the 1918 eruption of Bulusan, Mayon remained quiet and did not show any sympathetic action. The Bulusan ash showed marked similarity to the ash from Mayon, but A. D. Alvir has shown that the materials from Taal and Canlaon are likewise similar.

RECOMMENDATIONS

From the nature and habits of Mayon eruptions and judging from its appearance it is clear that eruptions of greater or less violence must be expected from time to time. It is likewise clear that man has no power to prevent future eruptions. The most that can be done is to take precautionary measures to prevent greater destruction of life and property.

Mention has been made that the railroad and the provincial road cross at several places around the base of the volcano. It would be desirable to have these crossings eliminated because in the event of a violent eruption these crossings will be veritable death traps for the people fleeing along the provincial road. Even during normal times passenger-carrying trucks and other vehicles and the trains are liable to have disastrous collision at these points. To have railroad bridges over all road crossings would entail an outlay of considerable funds but it is believed that the resulting protection would be well worth the expenditure.

Certain portions of Mayon Volcano now classified as public land and subject to legal occupation as agricultural land should be withdrawn from entry. The writer has noticed on several occasions homestead notices on alluvial fans and other places directly in front of the big ravines and barrancos. Disregarding the dangers of volcanic eruptions these places are not safe on account of sand and gravel and bowlder floods which may come at any time without previous warning. There are records of floods on the slopes of Mayon which were as disastrous if not more so to human lives and property as any of its violent eruptions. It would be desirable to have Mayon declared a public park and a line drawn around the base to limit the entry

of homesteaders and others. The Bicol region has available for entry large areas of public land more suitable for agriculture, and for the protection of the people this step is considered imperative.

The establishment of a seismograph station at the base of Mayon is strongly recommended. Periodic eruptions of Mayon must be expected, and the danger of a violent eruption is not without the range of probability. It would be extremely desirable to be able to warn the people and give them sufficient time to flee for safety. It is just as much a criminal offense to tell the people to vacate their homes and their property and cause a general exodus which would cause confusion and disorder and unnecessary expense and loss of livelihood as it is not to give the warning at the proper time. It must be remembered that at the most the data for a prediction are fragmentary and every means known to science should be available and ready for use. The Government official in charge of giving the warning has no middle course to follow; he must tell the proper time to make a quick get-away, not any sooner than necessary and certainly not later. During the 1928 eruption the concentration camps were ready, and if during any of the outbursts the warning to leave had been given it could not be assured that there would be no casualties in the confusion which would have followed. The concentration camps would have been filled with people and the expenses and trouble of keeping them there would have been considerable, not saying anything about the disease and sickness usually following such hasty concentrations. The Sakurajima volcanic eruption of 1914, which Jaggar considers as the greatest in the annals of the Japanese Empire, resulted in the loss of only thirty-five lives and some millions of dollars in property.

It was through a study of premonitory earthquakes in their relation to volcanic outbreaks that the Sakurajima eruption was definitely predicted; conversely, it is hoped that, in time, through exhaustive study of volcanic activities, earthquakes may be predicted with accuracy. If such forecasting can be achieved, it is conceivable that an earthquake of the severity of the Tokyo disturbance could occur with a loss of life and property almost negligible in comparison with what actually happened in September, 1923.

The phenomena of the Sakurajima eruption, therefore, are proving of transcendent importance to the scientific world, and the measures which were taken to safeguard life at that time are being eagerly studied anew.

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ILLUSTRATIONS

PLATE 9

FIG. 1. Looking across the crater of Mayon toward Tiwi, from the Daraga side. 1911. (Photograph by McDonald.)

2. Looking across the crater of Mayon toward Libog. 1911. (Photograph by McDonald.)

PLATE 10

FIG. 1. Looking across the crater of Mayon from the Libog lip toward Polangui. 1911. (Photograph by McDonald.)

2. Rocks at the bottom of the crater of Mayon. 1911. (Photograph by McDonald.)

PLATE 11

Mayon Volcano, showing glow of incandescent materials at night. Photograph taken from kilometer 9, Legaspi–Libog Road, June 28, 1928, 10 p. m. (Photograph by Cortez.)

PLATE 12

FIG. 1. Mayon Volcano, June 24, 1928. (Photograph by Cortez.)

2. Mayon Volcano, June 28, 1928. (Photograph by Cortez.)

PLATE 13

FIG. 1. Mayon Volcano, showing greater activity. July 8, 1928, 5 p. m. (Photograph by Photo Art Studio, Legaspi.)

2. Mayon Volcano in action. A towering column of dark eruption clouds reaching far into the sky, striking terror into the hearts of the people. July 19, 1928. (Photograph by Moderna Studio.)

PLATE 14

The weird fantastic shape assumed by eruption clouds over Mayon Volcano. July 20, 1928, 11.07 a. m. (Photograph by Photo Art Studio.)

PLATE 15

The crater cloud of Mayon Volcano. July 21, 1928.

PLATE 16

Mayon Volcano, puffing like a gigantic locomotive pulling up a steep grade. July 23, 1928. (Photograph by Moderna Studio.)

PLATE 17

Dark ash clouds covering the sky above Mayon Volcano. August 1, 1928, 5.30 a. m. (Photograph by Moderna Studio.)

PLATE 18

Advancing front of the lava on Mount Mayon, showing the character of the material. July, 1928. (Photograph by Wiley.)

PLATE 19

Mount Mayon, along one of the ravines, showing mantle deposit of volcanic dust and ash and volcanic bowlders at the bottom. July, 1928. (Photograph by Wade and Franks.)

PLATE 20

Ash cloud directly over the observers shortly after one of the periodic outbursts of Mayon Volcano. July, 1928. (Photograph by Wade and Franks.)

PLATE 21

Lava from the advancing front on Mount Mayon. Collected by Father Selga, August 29, 1928.

TEXT FIGURES

FIG. 1. Map of Mayon and the neighboring towns in Albay Province.
2. The form of cinder cones.
3. Sketch drawn to scale showing the relation between the cone of Mayon and the towering column of eruption clouds spreading at the top during one of the periodic outbursts. (Modified after Perret.)

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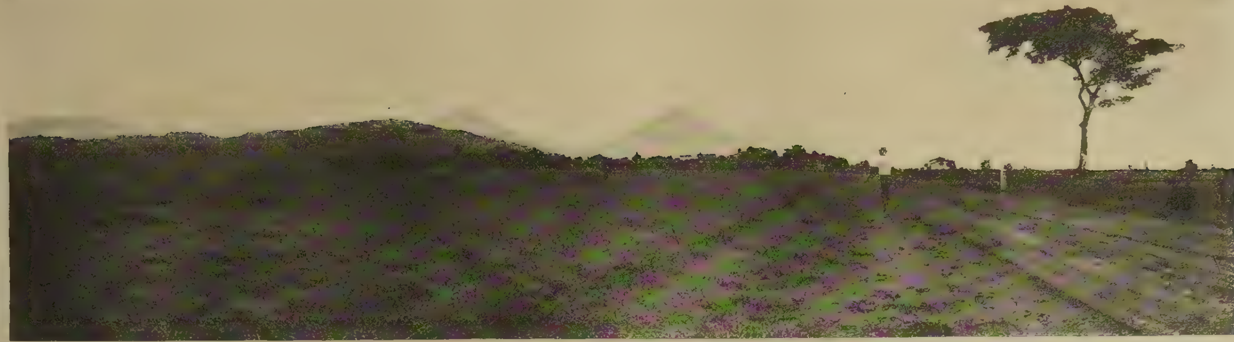

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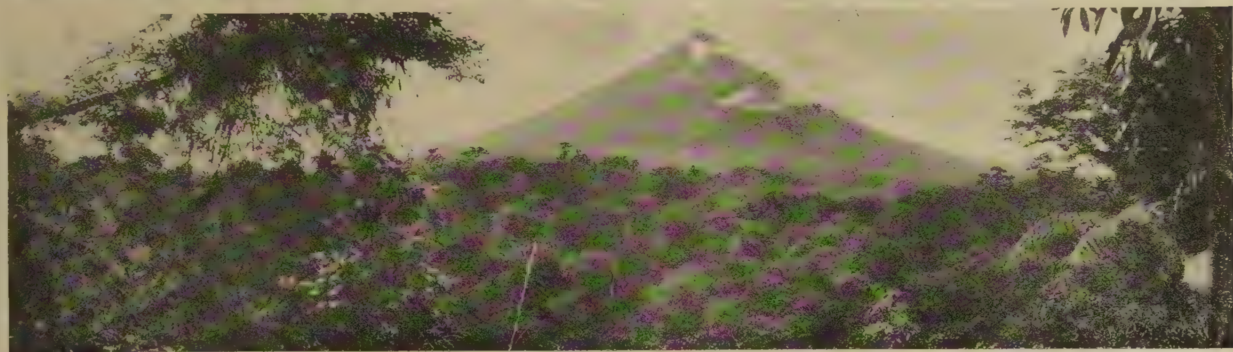

PLATE 1. MAYON VOLCANO, ABOVE, FROM LIGAO; BELOW, FROM TABACO.

PLATE 2. MAYON VOLCANO, FROM A DISTANCE OF 15 KILOMETERS.

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PLATE 3.

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PLATE 4.

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PLATE 5.

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PLATE 6.

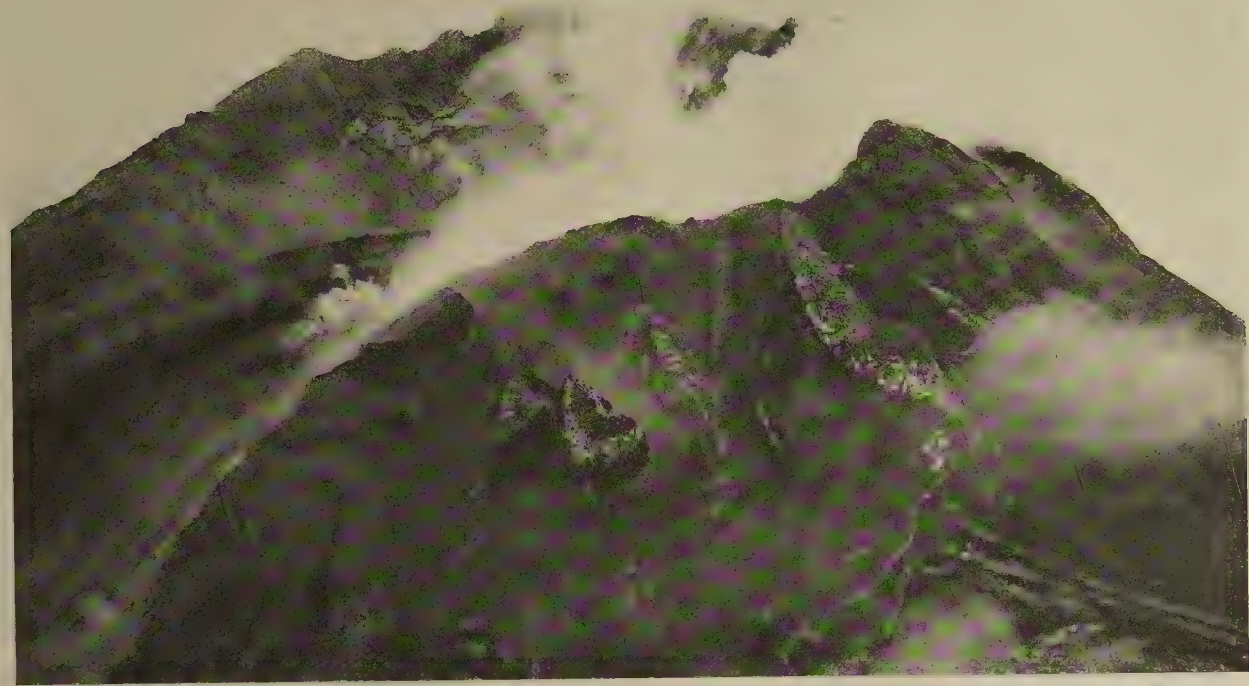

PLATE 7. AIRPLANE VIEW OF MAYON CRATER, SHOWING GASES AND MAIN CHUTE.

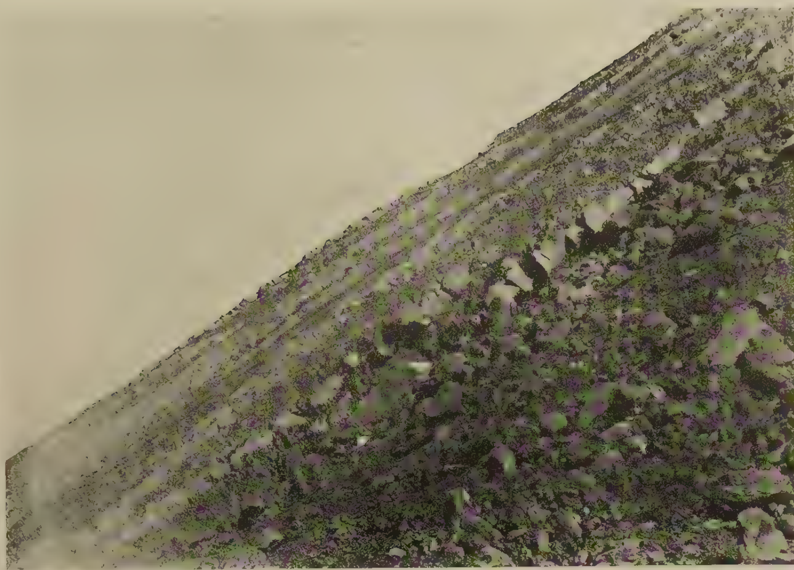

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PLATE 8.

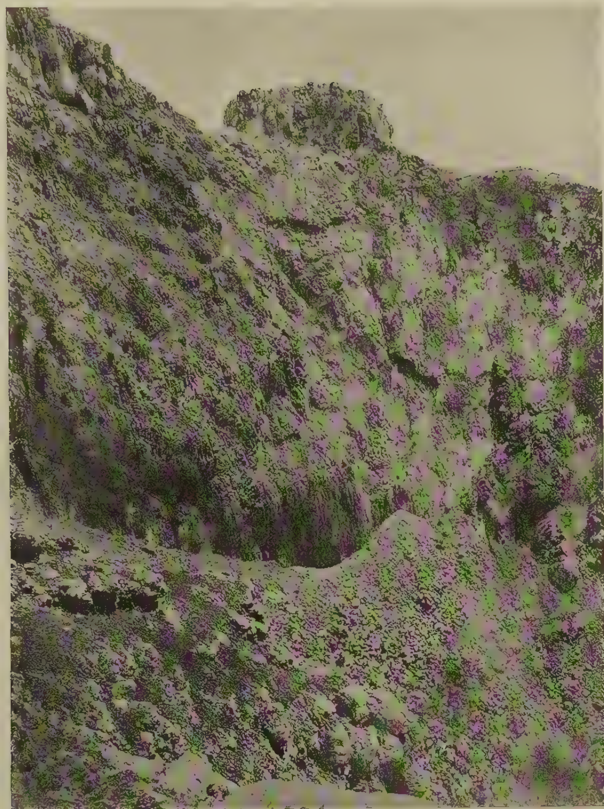

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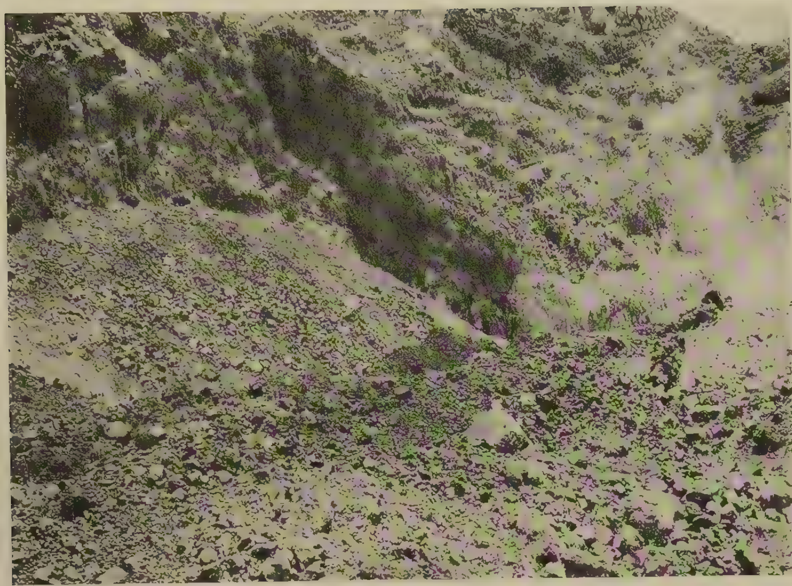
PLATE 9.



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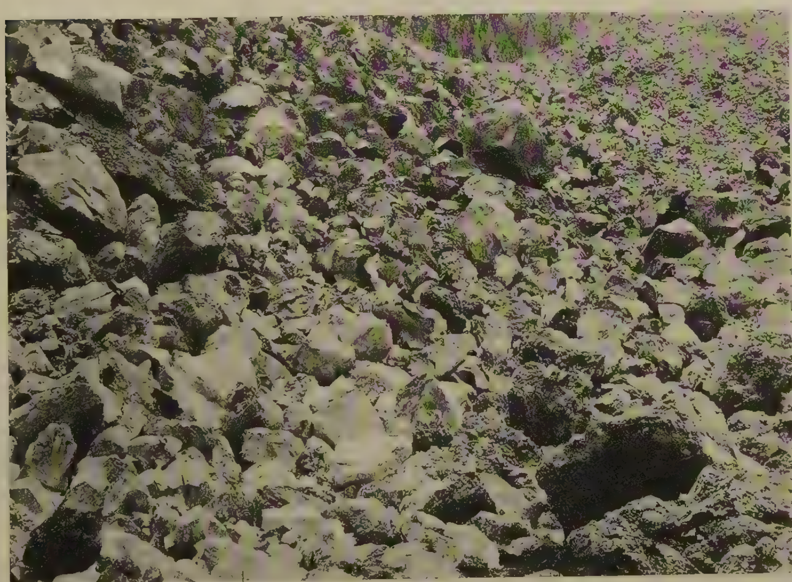

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PLATE 10.

PLATE 11. MAYON VOLCANO AT NIGHT, SHOWING GLOW OF INCANDESCENT MATERIAL.

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PLATE 12.

1

2

PLATE 13. MAYON VOLCANO IN ACTION.

PLATE 14. ERUPTION CLOUDS OVER MAYON.

PLATE 15. THE CRATER CLOUD OF MAYON.

PLATE 16. MAYON IN ERUPTION, JULY 23, 1928.

PLATE 17. DARK ASH CLOUDS ABOVE MAYON.

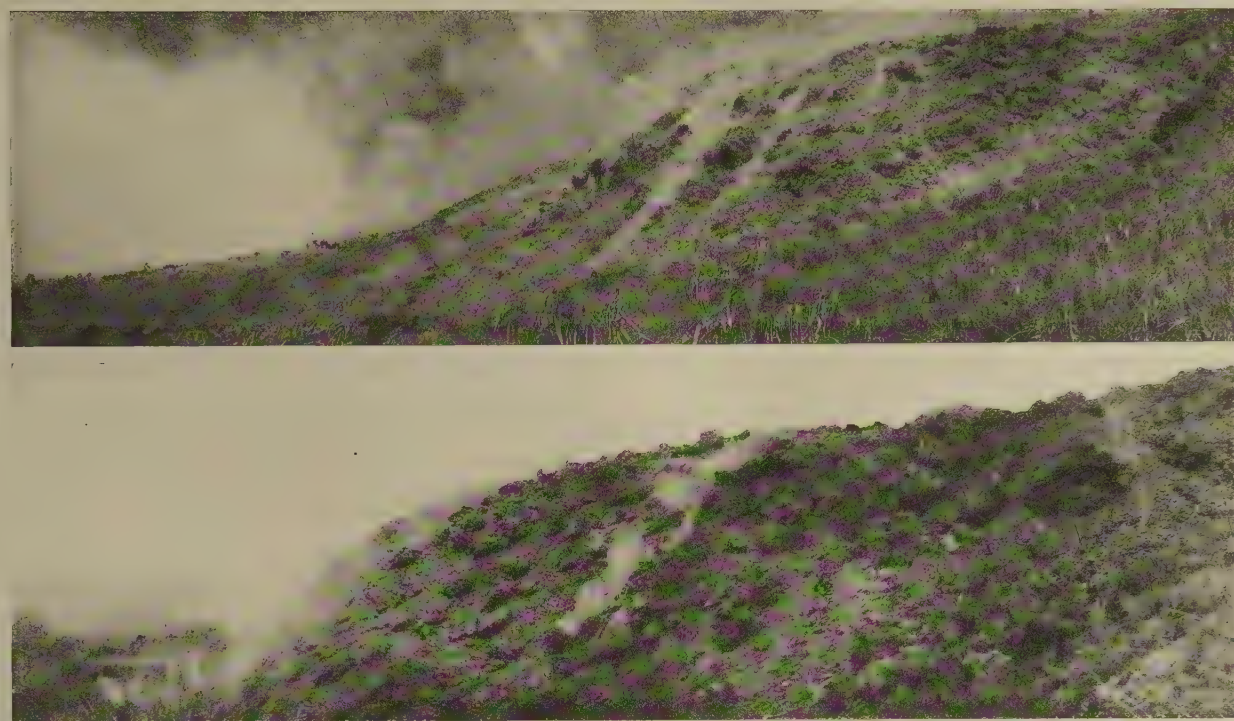

PLATE 18. ADVANCING FRONT OF LAVA ON MOUNT MAYON.

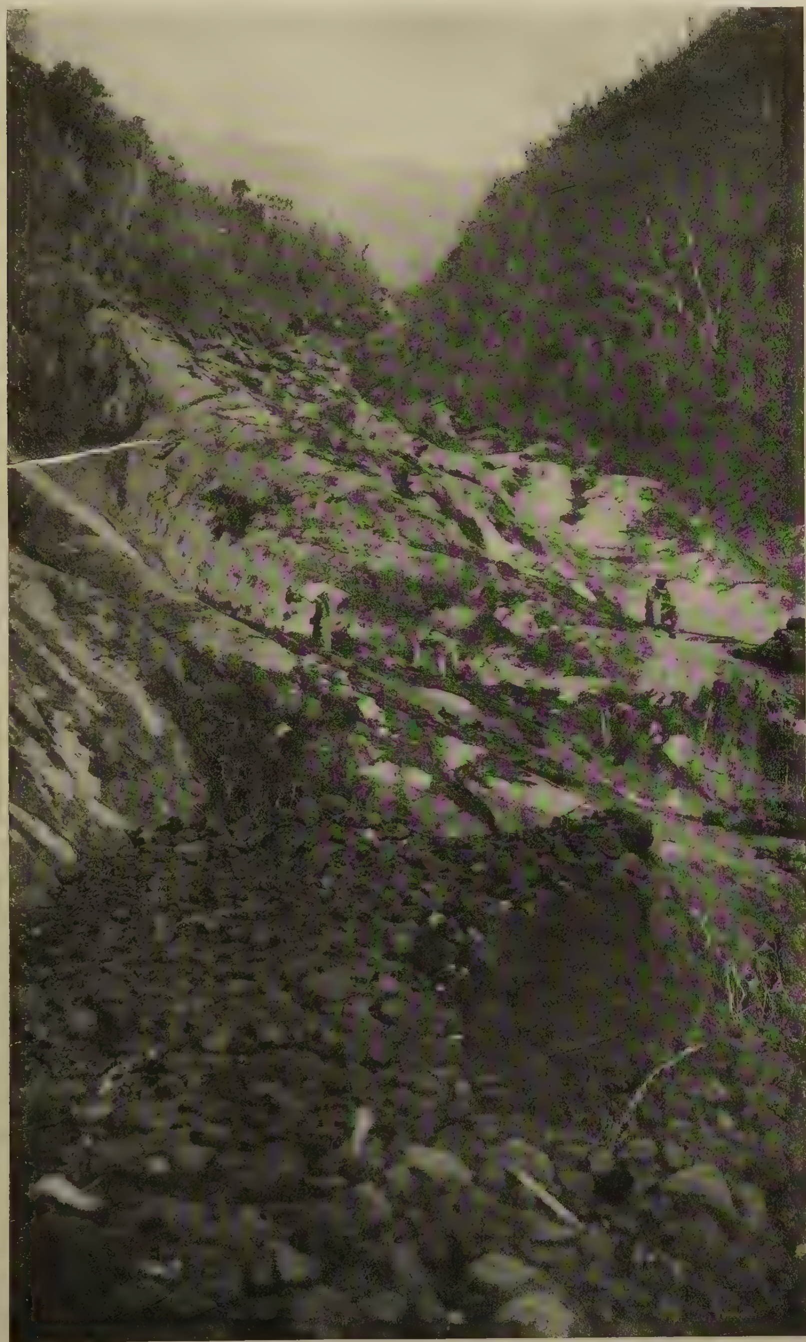

PLATE 19. ONE OF THE RAVINES ON MOUNT MAYON.

PLATE 20. AN ASH CLOUD DIRECTLY OVERHEAD.

PLATE 21. LAVA FROM THE ADVANCING FRONT, MOUNT MAYON.

NOTE ON THE DURATION OF IMMUNITY TO YAWS IN PHILIPPINE MONKEYS [1]

By B. TANABE [2]

Of the Division of Biology and Serum Laboratory
Bureau of Science, Manila

Sufficient evidence is on hand that resistance to yaws exists in yaws-infected animals [3] and men.[4] The dependence of the development of this resistance upon the time factor has been clearly demonstrated. There are some experiments indicating that once the resistance has developed it lasts for a considerable time. This fact has been substantiated in experiments on human volunteers and on animals. In the Philippines it has been found that the resistance lasts at least two years.

The object of the present investigation was to ascertain, first, whether or not this long duration of resistance is generally true in all cases or is subject to individual variations; and, second, whether or not the resistance to inoculation lasts longer than two years.

A long series of animals in which the yaws had healed was selected for this experiment. These animals were inoculated at various intervals after the original inoculation. The inoculations were well controlled by simultaneous inoculations made on normal control animals to prove that the inoculum contained viable treponemas. The technic of inoculation was the same as described previously from this institution.[5]

Table 1 shows the results of this experiment. The animals are arranged according to the length of time that elapsed between the first successful inoculation with yaws and the test for resistance.

[1] Received for publication, December 14, 1928.
[2] Lieutenant Colonel, Imperial Japanese Army.
[3] Philip. Journ. Sci. 35 (1928) 279.
[4] Philip. Journ. Sci. 22 (1923); 30 (1926) 465.
[5] Philip. Journ. Sci. 35 (1928) 216.

TABLE 1.—*Tests for duration of resistance in yaws-infected Philippine monkeys.*

[All normal control animals developed yaws; D, died; —, no lesion (immune). For the sake of easier calculation the months are indicated by Roman numerals, the days and years by Arabic figures.]

Designation of monkey.	Date of first successful inoculation.	Last test for resistance.		Result of the test for resistance.	Under observation until—
		Date.	Months after the first inoculation.		
			Months.		
W-2	VIII- 6-27	III-27-28	7	—	VIII-16-28 D.
D-14	VII-18-27	III-27-28	8	—	IV-3-28 D.
B-6	IV-12-27	I-24-28	9	—	XI-30-28.
C-6	IV-18-27	I-25-28	9	—	VI-18-28.
Y-4	V-31-27	III-27-28	10	—	XI-30-28.
G-10	IV- 4-27	III-27-28	11	—	IV-13-28 D.
O-d	III-11-27	III-27-28	12	—	XI-30-28.
B-5	I-15-27	I-24-28	12½	—	XI-30-28.
P-13	II- 1-27	III-26-28	13	—	XI-30-28.
K-7	I-15-27	III-26-28	14	—	XI-30-28.
G-9	I-24-27	III-27-28	14	—	IV-3-28 D.
J-15	XI- 5-26	III-26-28	15	—	XI-30-28.
J-16	XI- 5-26	III-26-28	15	—	XI-30-28.
H-20	XI- 8-26	III-26-28	15	—	XI-30-28.
L-6	XI-15-26	III-26-28	15	—	XI-13-28 D.
A-6	I- 6-27	IV-11-28	15½	—	XI-30-28.
A-7	I-11-27	IV-11-28	15½	—	X-23-28 D.
M-4	IX-13-26	III-26-28	17	—	IV-13-28 D.
E-17	XI-26-26	IV-11-28	17	—	XI-30-28.
E-16	X-27-26	IV-11-28	18	—	IV-30-28 D.
T-4	VII- 2-26	III-26-28	20	—	XI-30-28.
T-10	VII-20-26	III-25-28	20	—	X-1-28 D.
O-c	VI-27-26	III-26-28	21	—	XI-30-28.
C-2	III- 8-26	I-25-28	22	—	X-31-28 D.
J-11	III-19-26	III-26-28	24	—	XI-30-28.
L-5	III-24-26	III-26-28	24	—	XI-30-28.
D-8	IV-25-25	II- 4-28	33¾	—	XI-30-28.
B-K-3	V-23-25	IV-11-28	34	—	VI-28-28 D.

The following conclusions can be drawn from these experiments:

Without exception the duration of the resistance once developed in healed-yaws animals is long. The period of time that elapsed between the original inoculation with yaws to the final test for resistance in these experiments ranges from seven to thirty-four months. There is every reason to believe that the resistance to yaws in Philippine monkeys persists throughout life.

These experiments complete and amplify the evidence already afforded by the results previously published from this institution,[6] and show that the immunity lasts longer than two years.

The animals that were tested for immunity were kept under observation for the periods indicated in the table. I observed these animals up to May 15, 1928; after my departure from Manila the inspection of the animals was continued by Dr. Otto Schöbl and Dr. I. Miyao, and for their courtesy I here record my thanks.

[6] Philip. Journ. Sci. 35 (1928) 216.

SEROLOGIC STUDIES IN EXPERIMENTAL YAWS [1]

By Otto Schöbl

Chief, Division of Biology and Serum Laboratory
Bureau of Science, Manila

Part of the program in our inquiry into the problem of experimental yaws was the study of serologic changes as they occur in experimental frambœsia in Philippine monkeys.

The behavior of the Wassermann reaction in experimental infection and in immunity following the experimental infection has been dealt with in a previous report of our experiments.[2] The conclusions are reproduced here for the convenience of the reader.

14. The Wassermann reaction is indefinite and ephemeral in the case of early local yaws. Its strength and persistence depend upon the duration of infection, the number of yaws lesions, the intensity of the lesions, and, to a lesser extent, on the number of superinoculations.

15. The Wasermann reaction, if it has become negative due to treatment or spontaneous healing and if all the lesions have disappeared, will reappear upon unsuccessful superinfection or reinoculation with viable material.

16. The serologic reactivity of the body organism to superinfection (that is, the reappearance of Wassermann reaction) and the reactivity of the organism to treatment, which manifests itself as a disappearance of the Wassermann reaction becomes sluggish upon repeated reinoculations and treatments.

17. The reappearance of a postive Wassermann reaction can be produced in healed and cured animals without recurrence of yaws lesions and, therefore, a positive Wassermann reaction does not necessarily mean the existence of viable Treponema pertenue in the body organism of the animal.

Since then further experiments have been projected by the senior author and performed in collaboration with guests and staff members of the Bureau of Science with the purpose of elucidating by experimental means certain points concerning the nature of the so-called "reagin" of the Wassermann and

[1] Received for publication, December 14, 1928.

[2] Philip. Journ. Sci. 35 (1928) 261.

allied reactions. Perhaps additional use in practical medicine can be found in the interpretation of coördinated results of these serologic reactions in treponematoses.

The embarrasingly voluminous literature concerning the serology of treponematous diseases is surprisingly wanting in experimental evidence. The Wassermann reaction has been from the beginning a clinical method. Consequently the use of this reaction has been almost exclusively diagnostic or indicative of the efficacy of the treatment. The possibilities of its prognostic value have apparently remained unnoticed. The broader questions dealt with in these experiments were the following:

1. Is the Wassermann reagin, so called, a true antibody as we understand this term in bacterial immunity and is its peculiar nature due to the peculiarity of the microörganism which causes its appearance in the infected body or is it a phenomenon utterly different from those accompanying bacterial immunity?

2. Does the positive Wassermann reaction necessarily and without exception mean the presence in the body organism of living treponemas, or may it persist after these have been killed or have disappeared from the body?

In these experiments answers to the following questions were sought:

1. Is the yaws antigen which produces positive Wassermann reaction when injected into the body thermostable and to what degree?

2. Is there a relation between the number of vaccinations with yaws antigen and the strength of the Wassermann reaction that develops in consequence thereof?

3. Is there a relation between the time of appearance of the Wassermann reaction and the number of vaccinations?

4. What is the effect of infection upon the Wassermann reaction as produced by yaws vaccination?

5. Once a positive Wassermann reaction is produced by vaccination, how long may it last?

6. What is the effect of yaws revaccination upon the Wassermann reaction as produced by vaccination?

7. Is the Wassermann reaction produced in experimental animals by vaccination a specific reaction?

8. Following subcutaneous injection of yaws vaccine is the skin proper or the lymphatics or the muscle responsible for the appearance of positive Wassermann reaction?

9. What is the relation, with regard to treponema antigen, of the Wassermann reaction to the reactions the underlying principle of which is precipitation of antigen (Kahn test)?

In a previous communication [3] one of us noted an observation which led to the investigations presented in these papers.

When normal Philippine monkeys were injected subcutaneously with yaws material in such a manner that the development of skin lesion was prevented they showed a strong Wassermann reaction. They were kept under observation for a considerable time and failed to develop any clinical sign of yaws aside from positive Wassermann reaction. The conventional explanation of this phenomenon would take it for granted that latent infection was induced by this manner of inoculation. Previous observations of our own on experimental animals [4] and humans,[5] and observations of others on humans,[6] led us to suspect that a positive Wassermann reaction in yaws does not necessarily indicate the presence in the patient's or in the experimental animal's body of viable treponemas. When yaws lesions heal in the early stage, either spontaneously or due to specific treatment, all the clinical manifestations disappear, but the positive Wassermann reaction may persist for months before it disappears, and the patient or the experimental animal may live for years without any relapse whatsoever of clinical yaws, enjoy good health, have the appearance of a healthy robust individual, and give in due time repeatedly negative Wassermann reaction.

In order to demonstrate experimentally whether or not a positive Wassermann reaction necessitates the presence in the body organism of viable treponemas the experiments herewith presented were performed. It may be that a stage of latency has developed in the experimental animals used in the above-quoted experiments which may or may not lead to relapse later on. On the other hand, the possibility exists that the body tissues have been so sensitized by the infection that they continue for some time to produce Wassermann reagin in spite of the fact that stimulation of the tissues by the presence of live treponemas in the body has ceased. One is inclined to decide in favor of the last supposition because it is easily demonstrable

[3] Philip. Journ. Sci. 35 (1928) 295.

[4] Loc. cit.

[5] Schöbl, Otto, and José Ramirez, Philip. Journ. Sci. 30 (1926) 483.

[6] Navarro, R., Philip. Journ. Sci. 30 (1926) 445.

in yaws infection that Wassermann reaction which became negative either spontaneously or due to treatment can readily be made to reappear upon superinfection even though the superinfection takes place in the resistant stage and does not result in a clinical lesion. Consequently, more experiments were arranged to elucidate this point if possible. The results are presented in the following series of papers.

EXPERIMENTS CONCERNING THE YAWS ANTIGEN WHICH PRODUCES POSITIVE WASSERMANN REACTION WHEN INJECTED IN SUITABLE EXPERIMENTAL ANIMALS [1]

By OTTO SCHÖBL and BUNSHIRO TANABE [2]

Of the Division of Biology and Serum Laboratory
Bureau of Science, Manila

ONE TEXT FIGURE

EXPERIMENTAL PROCEDURE

Before we commence the description of individual experiments we wish to make certain general remarks concerning the technic of the Wassermann reaction as used in these experiments, and the interpretation of the results.

The technic was the same as described on previous occasion.[3] That is to say, both alcoholic antigen and cholesterinized antigen were used. Guinea pig pooled complement and antimonkey hæmolytic system were employed. The readings of the inhibition of hæmolysis as given in the tables in this paper refer to cholesterinized antigen and ten times diluted complement. In our rather extensive experience with human yaws we have frequently noticed that the inhibition in case of yaws serum is particularly strongly pronounced with the cholesterinized antigen. This, of course, is true as well of syphilis but it rarely happens, if ever, that syphilitic serum gives complete inhibition with cholesterinized antigen and a complete hæmolysis with the same antigen without cholesterine. This is frequently the case both in human and experimental yaws. These apparent differences in the behavior of the syphilitic and frambœsic serum, however, are not such as to guarantee a reliable serologic differential diagnosis between syphilis and yaws. We have re-

[1] Received for publication, December 14, 1928.

[2] Lieutenant Colonel, Imperial Japanese Army. Colonel Tanabe collaborated in these experiments up to his recall May 15, 1928.

[3] Schöbl, Otto, and Carlos Monserrat, Philip. Journ. Sci. § B 12 (1917) 249.

peatedly noticed in our yaws animals, either infected or vaccinated, that their serum will give strong inhibition with cholesterinized antigen but none at all with alcoholic. If the Wassermann reaction in experimental yaws monkeys continues over the stage resistant to inoculation and particularly when it is reenforced by repeated vaccinations, the positive Wassermann with the alcoholic antigen will make its appearance very frequently. Thus we may conclude that it is a difference of degree rather than of kind. Although no significance can be attributed to this phenomenon from the point of differential diagnosis, there is again an agreement between the serologic findings in man and in experimental yaws in monkeys. The interpretation of our findings must be made with this in mind. Nineteen monkeys were used in these experiments, and the results are arranged in tables so that the desired information may be obtained at a glance.

RESULTS OF EXPERIMENTS

In Table 1 experiments are registered that were made with the view of ascertaining the thermostability of the antigen in question.

Repeated injections of the vaccine were made under the skin of the abdomen and the chest at intervals of about a week. The skin was disinfected with alcoholic bichloride solution before and after the insertion of the needle.

As recorded in Table 1 some of the series of monkeys used in this experiment received unheated vaccine, others received vaccine heated for one hour at 60° C., others at 80° C., and still others at 100° C. Approximately one month after the first vaccination the blood was withdrawn from the heart of the animal and subjected to Wassermann test. It can be seen from the results tabulated herewith that the antigen producing positive Wassermann in yaws when injected into experimental animals does so irrespective of whether the material is alive or heated. In other words, its thermostability is considerable. These results dispose of the supposition that would take latent infection as an explanation for the occurrence of positive Wassermann reaction in animals repeatedly injected with unheated yaws vaccine without production of yaws lesions. The viability of our strain of Treponema framboesiæ has been studied in this laboratory by Yasuyama [4] and it was experimentally demonstrated

[4] Philip. Journ. Sci. 35 (1928) 333.

TABLE 1.—*Is the treponema antigen thermostable and to what degree?*

[—, no inhibition; ±, less than 25 per cent inhibition; +, 25 per cent inhibition; ++, 50 per cent inhibition; +++, 75 per cent inhibition; ++++, 100 per cent inhibition; 0, not done.]

Designation of monkey.	Number of vaccinations and the dates of first and last vaccination.				Vaccine.		Wassermann reaction before vaccination.	Date and result of Wasserman reaction after vaccination.
					Not heated.	Killed.		
N-12	1. II- 3-27	2	3	4. III- 9-27	+		0	V-12-27 ++++
D-12	1. II- 3-27	2	3	4. III- 9-27	+		0	V-12-27 +++
W-22	1. I-19-28	2	3. II- 8-28		—	+ 60° C. 1 hr.	—	I-31-28 +++
W-23	1. I-19-28	2	3. II- 8-28		—	+ 60° C. 1 hr.	—	I-31-28 ±
W-57	1. III- 5-28	2	3. III-20-28		—	+ 80° C. 1 hr.	—	IV-7-28 +++
W-58	1. III- 5-28	2	3. III-20-28		—	+ 80° C. 1 hr.	—	IV-7-28 ++++
A-8	1. IV-11-28	2	3. IV-27-28		—	+ 100° C. 1 hr.	±	V-17-28 +
K-9	1. IV-11-28	2	3. IV-27-28		—	+ 100° C. 1 hr.	±	V-17-28 +

that Treponema framboesiæ does not live long outside of the body. Control animals in our experiments when inoculated intradermally with the vaccine persistently failed to develop yaws. There is no doubt, therefore, that the treponemas contained in the vaccine as used in these experiments were dead. Consequently a positive Wassermann reaction can be induced in suitable experimental animals with dead treponemas, and actual infection is not the only cause of a positive Wassermann reaction.

TABLE 2.—*The relation between the number of injections of yaws vaccine and the strength of the Wassermann reaction.*

Designation of monkey.	Number of weekly vaccinations.	Vaccine.		Wassermann reaction before vaccination.	Result of Wassermann reaction after vaccination.
		Unheated.	Killed.		
N-12	4	+		0	++++
D-12	4	+		0	+++
W-22	3		+ 60° C. 1 hr.	—	+++
W-23	3		+ 60° C. 1 hr.	—	±
W-57	3		+ 80° C. 1 hr.	—	+++
W-58	3		+ 80° C. 1 hr.	—	++++
W-26	2		+ 60° C. 1 hr.	—	++
W-27	2		+ 60° C. 1 hr.	—	+
W-25	2		+ 60° C. 1 hr.	—	±
W-59	2		+ 80° C. 1 hr.	—	++
W-60	2		+ 80° C. 1 hr.	±	+
E-40	1		+ 60° C. 1 hr.	—	—
E-41	1		+ 60° C. 1 hr.	—	—
W-39	1	+		—	—
W-61	1		+ 80° C. 1 hr.	—	—
W-62	1		+ 80° C. 1 hr.	—	—

The relation between the number of injections of yaws vaccine and the strength of the Wassermann reaction was investigated on a series of experimental animals (Table 2) that received decreasing numbers of vaccinations in the manner just described. Two monkeys received four injections of unheated vaccine; four monkeys received three injections of heated vaccine; five monkeys received two injections of heated vaccine; one monkey received one injection of unheated vaccine and four monkeys received one injection of heated yaws vaccine.

We can see at a glance that the strongest Wasserman reactions occurred in the monkeys that received the largest numbers of vaccinations, while those monkeys that received only one vaccination were negative at that time. The monkeys that were

vaccinated four times showed an average of 3.50 pluses. The ones that received three vaccinations showed an average of 2.625. Those that received two injections showed an average of 1.30 pluses. There is a steady decrease of the strength of the Wassermann reaction following the decrease in the number of vaccinations. There are, however, individual variations. This may be due to the quantity factor or to the time factor. In other words those animals that received a lesser number of injections may develop positive Wassermann reaction later than those that received more vaccinations. This question will be treated together with the duration of the positive Wassermann reaction as produced by vaccination.

TABLE 3.—*What is the effect of infection upon Wassermann reaction as produced by yaws vaccination?*

Designation of monkey.	Number of vaccinations.	Vaccine.		Wassermann reaction before vaccination.	Wassermann reaction after vaccination.	
		Unheated.	Killed 1 hour at—		Before infection.	After infection.
H-12	4	+		0	++++	++++
D-12	4	+		0	+++	++++
W-22	3		+ 60° C. 1 hr.	—	+++	++++
W-23	3		+ 60° C. 1 hr.	—	±	+++
W-26	2		+ 60° C. 1 hr.	—	+±	±+++
W-27	2		+ 60° C. 1 hr.	—	+	++++
W-25	2		+ 60° C. 1 hr.	—	±	++++
E-40	1		+ 60° C. 1 hr.	—	—	—
E-41	1		+ 60° C. 1 hr.	—	—	+
E-39	1	+		—	—	±
Average of pluses					1.55	3.18

The effect of infection with viable treponemas upon the Wassermann reaction as produced by yaws vaccination is evident from Table 3. Three groups of vaccinated animals were selected for this purpose; one group of two animals with strong Wassermann reaction, another group of five animals with moderately strong, and one group of three animals with negative Wassermann. The Wassermann test was performed before the infection with live material took place. It was then repeated approximately one month after the infection. There is a constant increase of the strength of the Wassermann reaction in the vaccinated animals after the infection. The last three animals that before vaccination showed negative Wassermann make an

exception. They received only one vaccination and were reexamined about a month after the infection. There was a slight increase of Wassermann in two cases out of three at the time the animals were examined. This last group behaves with respect to Wassermann reaction in the same manner as do normal monkeys infected for the first time.[5]

The persistence of the Wassermann reaction after vaccination was investigated in a group of five animals (Table 4). Two of them received three vaccinations and showed a strong Wassermann reaction about one month after vaccination; two of them received two vaccinations and showed moderately positive Wassermann reaction; and one of them received one vaccination and showed negative Wassermann reaction. In this experiment not only the duration was investigated but also the question whether or not the time factor enters into the appearance of a positive Wassermann reaction. That is to say, whether or not the animals that received only one injection develop a positive Wassermann reaction later than those that received more than one injection.

In addition to these five animals, two monkeys were injected with diluted vaccine three times at weekly intervals. This was done to bring out the quantitative relation of the amount of the vaccine, and the strength of the serum reaction and the time at which the positive Wassermann reaction becomes detectable by the method employed in our investigation. The result of this experiment is presented in Table 4.

The two animals that received three vaccinations at weekly intervals and gave negative result prior to vaccination showed strong Wassermann reaction when examined about one month after the first vaccination, a moderately positive Wassermann reaction two months after the first vaccination, and a negative result when reëxamined two months and three weeks after the first vaccination.

The two monkeys that received two vaccinations and were negative or gave a plus-minus Wassermann reaction prior to the vaccination showed weak and moderate Wassermann reaction respectively one month after the first vaccination, a doubtful and weak Wassermann reaction two months after, and doubtful reaction two months and three weeks after the first vaccination.

[5] Philip. Journ. Sci. 35 (1928) 261–272.

TABLE 4.—*Following vaccination how long may the Wassermann reaction last?*

Designation of monkey.	Vaccinations.						Vaccine heated for 1 hour at—	Wassermann reaction before vaccination.	Date and result of Wassermann reaction after vaccination.	
	Number.	Date.	Number.	Date.	Number.	Date.				
W-57	1	III-5-28	2	III-12-28	3	III-20-28	+ 80° C	—	IV- 7-28 V- 3-28 V-28-28	+++ ++ —
W-58	1	III-5-28	2	III-12-28	3	III-20-28	+ 80° C	—	IV- 7-28 V- 3-28 V-28-28	+++ + —
W-59	1	III-5-28	2	III-12-28			+ 80° C	—	IV- 7-28 V- 3-28 V-28-28	++ + ±
W-60	1	III-5-28	2	III-12-28			+ 80° C	±	IV- 7-28 V- 3-28 V-28-28	+ ± ±
W-61	1	III-5-28					+ 80° C	—	IV- 4-28 V- 3-28 V-28-28	— + +
W-63	1	III-5-28	2	III-14-28	3	III-20-28	+ 60° C [a]	—	IV- 7-28 V- 3-28 V-28-28	— ± —
W-64	1	III-5-28	2		3	III-20-28	+ 60° C. [a]	±	IV- 7-28 V- 3-28 V- 28-28	± + —

TABLE 5.—*What is the effect of revaccination upon Wassermann reaction produced by yaws vaccination?*

Designation of monkey.	Number of vaccinations.			Vaccine killed 1 hour.	Wassermann reaction before vaccination.	Wasserman reaction after vaccination. Before revaccination.	After 1st revaccination V-31-28.	After 2nd revaccination VII-17-28.
						+++ IV- 7-28	± VI-21-28	— VII-30-28
W-57	1	2	3	80° C.	—	++ V- 3-28	— VII- 5-28	0
						— V-28-28	— VII-17-28	0
						++ IV- 7-28	± VI-21-28	— VII-30-28
W-59	1	2	3	80° C.	—	+ V- 7-28	— VII- 5-28	0
						± V-22-28	— VII-17-28	0
						— IV- 7-28	++++ VI-20-28	— VII-30-28
						.	VI-21-28	
W-61	1	----	----	80° C.	—	+ V- 7-28	— VII- 5-28	0
						+ V-28-28	— VII-17-28	0

The three monkeys one of which received only one vaccination and the other two that were given three vaccinations with highly diluted vaccine showed no difference between the results of the tests performed prior to and one month after the vaccination but showed slight increase of inhibition two months and three weeks after the vaccination.

The effect of revaccination upon the Wassermann reaction in three yaws-vaccinated monkeys was studied in the following experiment (Table 5).

One of the three monkeys received three vaccinations and gave strong Wassermann reaction. Another monkey received three vaccinations and gave moderately positive result. The third one having received only one vaccination gave a weak and delayed Wassermann reaction. All of the three animals gave negative result prior to vaccination. The strength of the Wassermann reaction having been established in these animals as a result of vaccination, the time was awaited when the reaction had become negative in one animal, doubtful in another, and weak in the third. At this time the monkeys received one injection of yaws vaccine. The response to the new incorpora-

tion of yaws vaccine was very weak in the first two monkeys, which having received three vaccinations gave strong and moderate results, respectively. In the third animal which received only one vaccination and consequently showed weak and delayed Wassermann reaction the response to revaccination was very strongly pronounced; that is, a strong Wassermann reaction resulted. A second revaccination was performed when all of the three monkeys had reached serologic normalcy and gave negative results on two successive tests. The response to the second revaccination on the part of each of the three monkeys was nil.

DISCUSSION

In monkeys infected with yaws and treated the following findings were made:[6]

> When the process of alternating infection and treatment was continued for a long period of time, the promptness of disappearance of the Wassermann reaction after treatment and its reappearance after reinoculation was considerably decreased, and a stage was reached at times in which a low-grade Wassermann reaction persisted practically unchanged by either of the two procedures mentioned.

In yaws-vaccinated monkeys the same phenomenon of exhaustion on the part of the body organism of serologic reactivity to the incorporation of antigen can be discerned. The exhaustion of serologic reactivity sets in much earlier after vaccination than in actual yaws infection, because the impetus as well as the serologic response is more sudden in vaccination than in actual infection.

This statement is illustrated in fig. 1. The curves were drawn merely to show their shape and type. The intervening details may be found in the respective tables. The first seven curves represent the behavior of the Wassermann reaction during the process of repeated infections and cures interposed between the infections. They were compiled from a table previously published.[7] The last three curves illustrate the behavior of the Wassermann reaction following vaccination with killed Treponema framboesiæ without intervening treatment and were compiled from Table 5 attached to this paper.[8] Curve 1 referring to monkey B–3 of previous publication we consider as prototype. It shows a rise in the titre of the Wassermann reaction follow-

[6] Philip. Journ. Sci. 35 (1928) 333.
[7] Philip. Journ. Sci. 35 (1928) 274, Table 9.
[8] Philip. Journ. Sci. 40 (1929) 1.

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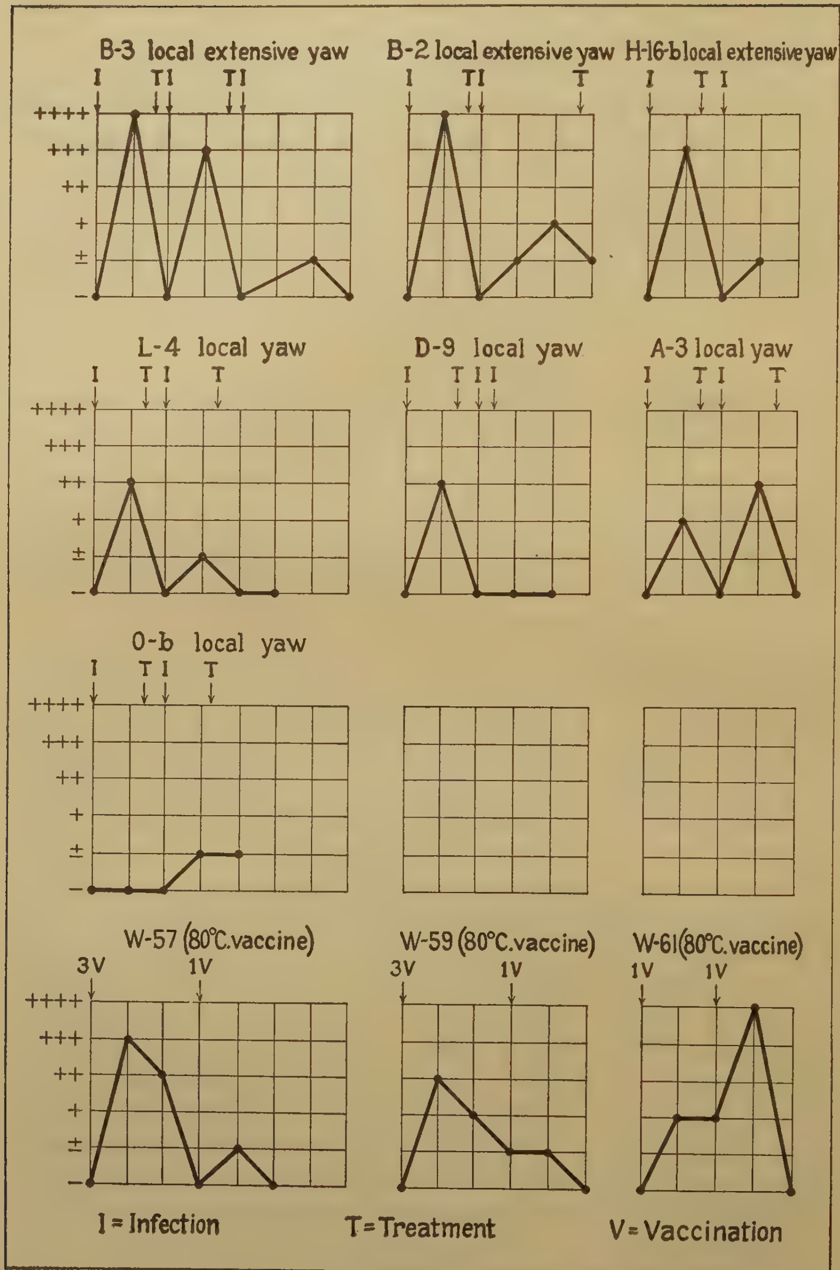

FIG. 1. Results of Wassermann reaction in repeatedly infected and cured monkeys compared with results obtained in repeatedly vaccinated monkeys.

ing infection with yaws. Then follows a drop caused by the treatment. When the Wassermann reaction disappeared another infection was performed in consequence of which the titre of the Wassermann reaction rose again only to drop to negative following a treatment. The third infection, performed when the Wassermann reaction had become negative, again caused a rise in the titre of the Wassermann reaction. In this typical case each following rise of the curve is less than the previous one, but on treatments the curve returned to zero. The second curve compiled from the record of monkey B–2 is a slight modification of the first one, the general course of the curve as far as it has been followed being the same. So is curve 3 (monkey H–16–B) and curve 4 (monkey L–4) but curve 5 (monkey D–9) shows only the initial rise. After the first infection it rose, then, following the treatment it dropped to zero and continued at zero. In other words the second rise following infection is absent. Nevertheless the curve follows the type of the previous ones.

The second type of curve obtained in this experimental investigation is evident from curves 6 and 7. The original infection produced a rise in Wassermann reaction and a drop to zero following the treatment (in animal A–3). The second infection performed at the time of serologic cure lifted the curve to a higher point than the first infection in the same monkey (A–3). Curve 7 is of the same general type as the previous one but the first rise is absent.

It is interesting, in view of our explanations of the behavior of the Wassermann reaction following infection with yaws and its relation to the severity of infection, to note that curves 1, 2, and 3 were observed in monkeys showing an extensive local lesion.

The last three curves (monkeys W–57, W–59, and W–61) are drawn from the results of Wassermann reactions performed on monkeys vaccinated with treponemas killed by heating at 80° C. for one hour. The first two (monkeys W–57 and W–59) received three vaccinations previous to the first test, and the response was strong as expressed by the degree of the positive Wassermann reaction. Revaccination given on the decline of the curve brought a far lesser serologic response than the first vaccination. These two curves (monkeys W–57 and W–59) follow the same type as the first curve in a repeatedly infected and

cured yaws monkey (B–3). It is significant that both these animals have received three vaccinations previous to the first test. In the last curve monkey W–61 received only one vaccination, and the response to that first vaccination was mild (+). Upon revaccination the curve rose to a higher point after which it dropped to zero. The last-mentioned curve (monkey W–61) is of the second type noticed in repeatedly infected and treated monkeys, that is the type of curve noticed in monkey A–3. From this illustration it is more clearly evident, than from the discussion, that the vaccination with killed Treponema framboesiæ produces results identical with those observed in repeatedly infected and treated monkeys. Likewise vigorous vaccination produces the same type of curve as vigorous infection while injection of a small amount of killed yaws vaccine produces the type of curve noticed in animals slightly reactive to infection.

SUMMARY AND CONCLUSIONS

1. Repeated subcutaneous injections of killed Treponema framboesiæ produce in Philippine monkeys a positive Wassermann reaction.

2. The strength of the Wassermann reaction is in direct proportion to the number of subcutaneous injections of killed treponemas.

3. The length of the pre-Wassermann stage in monkeys immunized with killed treponemas is in inverse proportion to the number of injections.

4. The positive Wasserman reaction in experimental monkeys, having reached its full strength as a consequence of repeated subcutaneous injections of killed treponemas, declines rather rapidly and in due time becomes negative.

5. The response of the body to the introduction of the lifeless antigen, which response manifests itself as a recrudescence of Wassermann reaction following revaccination administered after a period of negative reactions, becomes more and more sluggish with each subsequent revaccination.

6. The strength of the Wassermann reaction that follows the revaccination stands in inverse proportion to the strength of the reaction following the preceding vaccination, and, consequently, it is in inverse proportion to the amount of vaccination.

7. Individual variations in the serologic response exist in the animals used in our experiments.

ILLUSTRATION

TEXT FIG. 1. Chart showing results of Wassermann reaction in repeatedly infected and cured monkeys compared with results obtained in repeatedly vaccinated monkeys.

IS THE WASSERMANN REACTION PROVOKED IN PHILIPPINE MONKEYS BY YAWS VACCINATION SPECIFIC? [1]

By Isao Miyao [2]

Of the Division of Biology and Serum Laboratory
Bureau of Science, Manila

INTRODUCTION

It was demonstrated by Schöbl and Tanabe [3] that monkeys inoculated with killed yaws vaccine will show positive Wassermann reaction a certain time after the vaccination. The fact that the vaccinated animal's blood shows negative Wassermann reaction prior to, and positive reaction sometime after the vaccination may be taken as sufficient proof that this phenomenon is a specific Wassermann reaction. The quantitative relation between the strength of the reaction and the amount of vaccine or number of vaccinations leaves no doubt that the phenomenon under discussion is due to the vaccination.

However, the possibility of error must be considered, and it must be demonstrated that the treponemas originally present in the vaccine contain the substances which act in vivo as an antigen of the Wassermann reagin. Led by the idea of incriminating the treponemas in the vaccine as the responsible factor for the appearance of positive Wassermann reaction in vaccinated monkeys I have endeavored to eliminate the possibility of factors other than the treponemas.

In the experiment presented in this paper I have endeavored to eliminate the blood serum, the lymph, the normal and pathologic inflammatory cellular elements contained in the vaccine as well as the microörganisms that may be present in a superficial skin lesion, such as a yaws lesion. The procedure was as follows: The vaccine was filtered as soon as prepared. The filtrate obtained in such a way was used for subcutaneous injection into monkeys to ascertain whether or not the antigen is free in the

[1] Received for publication, December 14, 1928.

[2] Lieutenant Surgeon, Imperial Japanese Navy.

[3] Antea 57.

liquids of the lesion. The vaccines that were employed in this filtration experiment were tested separately for their antigenic potency. Furthermore, I attempted to eliminate the elements contained in the vaccine; that is, skin tissue and inflammatory cellular elements.

Although it was not likely that the skin and the inflammatory cellular elements would be responsible for the appearance of a positive Wassermann reaction it was not altogether impossible that tissues of yaws monkeys might have been changed to such a degree as to participate in the production of the reagin. Consequently, five experiments were carried out.

First, monkeys were injected repeatedly under the skin with the filtrate of fresh live yaws vaccine. Following this vaccination the blood was repeatedly tested for Wassermann reaction at the intervals of time given in the tables.

Second, normal skin of normal monkeys was scraped off, ground up, suspended in normal salt solution, and heated at 80° C. for one hour. Repeated injections of this emulsion were given after which the animal's blood was tested for Wassermann reaction.

Third, normal skin tissue of monkeys infected with yaws was used for the preparation of vaccine, as just described, and normal monkeys received repeated injections of this vaccine.

Fourth and fifth, in order to convince myself that nonspecific inflammatory tissue is not responsible for the production in vivo of the reagin, normal monkeys as well as yaws monkeys were vaccinated with smallpox vaccine on the normal part of the skin. When the take fully developed it was scraped off, ground up and heated, and used for repeated subcutaneous injections into normal monkeys. Following the vaccination with these various emulsions the animals showed negative Wassermann reactions on repeated examination. They were then infected with yaws and after the infection and superinfection their blood was again examined by Wassermann reaction to prove that those animals were capable of producing positive Wassermann.

From the tabulated results it can be seen that the filtrate of a potent yaws vaccine raised very slightly the Wassermann reaction. This shows that the antigen which produces positive Wassermann reaction when repeatedly injected under the skin of monkeys was to a great extent caught by the filter and only a very small part of it passed through. The filtrate of the yaws vaccine acted like the highly diluted vaccine.

TABLE 1.—*Showing the serologic results of subcutaneous injections of yaws vaccine from which treponemas have been removed by filtration through Berkefeld filter.*

Description of monkey.	Number of vaccinations.	Wassermann reaction.	
		Before vaccination.	After vaccination.
W-63-a	3	—	±
W-63-b	3	±	+

Experiments 2, 3, 4, and 5 are tabulated in Table 2. They show that repeated injections of normal skin as well as nonspecific exudative skin lesion from either normal or yaws monkeys failed to produce serologic changes in animals of the same species. The presence, therefore, in the vaccine of the treponemas is necessary for the production of positive serologic reactions. In other words the Wassermann reaction produced by yaws vaccine is specific.

CONCLUSIONS

These experiments show that repeated injections of normal skin tissue or inflammatory skin tissue from normal or yaws-infected monkeys failed to produce positive Wassermann reaction.

Repeated injections of potent yaws vaccine from which the treponemas have been removed by filtration produced no appreciable serologic change in monkeys.

These findings are sufficient proof that the presence in the vaccine of treponemas is necessary for the production of positive Wassermann reaction, and that this serum reaction produced by yaws vaccine is specific in the sense that it is an antibody produced by the antigen contained in the treponemas and not a mere consequence of an interaction between viable treponemas and body tissues.

TABLE 2.—*Showing the result of Wassermann reaction in monkeys immunized with normal and inflammatory tissues from normal skin of normal and yaws monkeys.*

[—, negative; ±, less than 25 per cent hæmolysis; +, 25 per cent hæmolysis; ++, 50 per cent hæmolysis; +++, 75 per cent hæmolysis; 0, not done; D, died.]

Designation of monkey.	Kind of tissue used for subcutaneous immunization.	Date and result of Wassermann reaction after immunization with normal and inflammatory tissues.		Date and result of infection with yaws.	Date and result of Wassermann reaction after infectfon and superinfection with yaws treponemas.						
R-3	Normal skin from normal monkeys.	VI-20-28 —	VII- 5-28 —	VII-19-28 D	IX-3-28 —	IX-13-28 —	IX-27-28 —	X-9-28 D			
R-4	do	VI-20-28 —	VII- 5-28 —	VII-19-28 IX-17-28 yaw	IX-3-28 —	IX-13-28 —	IX-27-28 —	X-9-28 —	X-23-28 +		
S-4	Normal skin tissue from yaws monkey.	VI-20-28 —	VII- 5-28 —	VIII- 2-28 Inoculated yaw	IX-3-28 —	IX-13-28 —	IX-27-28 —	X-9-28 —	X-23-28 ±		
a-1	Inflammatory skin tissues from normal monkey.	VII- 2-28 —	VII-16-28 —	VII-31-28 Inoculated yaw	IX-3-28 —	IX-13-28 ++					
a-2	do	VII- 2-28 —	VII-16-28 —	VII-31-28 Inoculated yaw	IX-3-28 —	IX-13-28 +++					
Z-1	Inflammatory skin tissues from yaws monkey.	VI-20-28 —	VII- 5-28 —	VIII- 2-28 Inoculated yaw	IX-3-28 —	IX-13-28 —	IX-27-28 —	X-9-28 —	X-23-28 —	X-30-28 —	XI-14-28 ±
Z-2	do	VI-20-28 —	VII- 5-28 —	VIII- 2-28 Inoculated yaw	IX-3-28 —	IX-13-28 —	IX-27-28 —	X-9-28 —	X-23-28 —	X-30-28 —	XI-14-28 ±

FOLLOWING THE SUBCUTANEOUS IMMUNIZATION WITH YAWS VACCINE IS THE SKIN TISSUE PROPER RESPONSIBLE FOR THE PRODUCTION OF WASSERMANN REAGIN OR DO OTHER TISSUES ALSO PARTICIPATE?[1]

By Isao Miyao[2]

Of the Division of Biology and Serum Laboratory
Bureau of Science, Manila

The object of this experiment was to find out whether the skin is the principal organ in which the Wassermann reagin in yaws is elaborated or whether other tissues also help in the production of this antibody. The object of this experiment was not to investigate each organ in the experimental animal's body with regard to the question under discussion but mainly to determine into what organ lifeless treponema antigen must be injected to obtain the best results. Consequently the ways of inoculations that are most customary in experimental investigation were applied; that is to say, the subcutaneous, the intraperitoneal, and the intramuscular injection of killed Treponema framboseiæ were given. It has been found that by subcutaneous inoculation of unheated or heated treponemas a positive Wassermann reaction can be produced.[3] It was the question to decide whether the cutis and the subcutaneous tissue, the muscles, or the lymphatic glands, with which the antigen must come in contact following the subcutaneous injection, are responsible for the serologic changes in the blood of the immunized animal. It was to be expected that the skin predominately is involved in the production of Wassermann reagin. This conclusion could be drawn from clinical observation and from experience with Wassermann reaction on yaws-infected monkeys. It is generally known that yaws patients with extensive early skin

[1] Received for publication, December 14, 1928.
[2] Lieutenant Surgeon, Imperial Japanese Navy.
[3] Antea 57.

manifestations give the strongest Wassermann reaction. This is also true in syphilis. In experiments with infected monkeys [4] it was found that the strength of the Wassermann reaction stands in direct proportion to the amount of skin involved by the yaws lesions. Nevertheless, a direct experimental demonstration was lacking. Furthermore, the question whether the skin or the lymphatic tissues are responsible for the appearance of the positive Wassermann reaction could not be deduced from clinical observations or previous experimental findings. It was therefore decided to undertake the experiment presented herewith.

A series of six monkeys was vaccinated with the same lot of yaws vaccine in three different ways; that is, two animals received three injections intraperitoneally, two animals received three injections intramuscularly, and two animals received two injections subcutaneously. This arrangement of vaccination was made with the purpose of demonstrating that the skin is the producer of the Wassermann reagin and not an endothelial lining like the peritoneum, the muscle tissue, or the regional lymph glands. For this reason only two subcutaneous vaccinations were given, while one more was given intraperitoneally and intramuscularly so as to eliminate the possibility of error due to higher dilution of the inoculation antigen in the peritoneum and in the muscles than that injected under the skin. These vaccinations were given at intervals of approximately one week, and about four weeks after the first vaccination the repeated tests of the blood began. All of the animals gave negative result when tested by the Wassermann reaction before and immediately after the vaccination. The animals having been examined at intervals of about two weeks it became apparent that only the two that received two injections of the yaws vaccine under the skin showed positive result, while the animals vaccinated by intraperitoneal and intramuscular injection showed no change whatsoever in their serologic behavior. In order to assure the correctness of these findings revaccination was performed slightly less than two months after the first vaccination. As a result of the revaccination there was a rise from weak to frank positive reaction in one, and from negative to weakly positive in another case of the subcutaneously vaccinated monkeys. After this the reaction declined to negative. The serologic picture in the animals that received intraperitoneal

[4] Philip. Journ. Sci. 35 (1928) 261.

TABLE 1.—*Showing the serologic results after subcutaneous, in traperitoneal, and intramuscular vaccination against yaws.*

[+, 25 per cent inhibition of hæmolysis; ±, less than 25 per cent inhibition of hæmolysis; —, complete hæmolysis; 0, not done.]

Designation of monkey.	Date and modus of vaccination.			Wassermann reaction. Results and dates.				Revaccination, VIII-4-28.	Wasserman reaction after revaccination.	
	First, VI-14-28.	Second, VI-22-28.	Third, VI-30-20.	Before vaccination, VI-30-28.	After vaccination.				VIII-16-28.	VIII-30-28.
					VIII-13-28.	VIII-27-28.	VIII-2-28.			
c-1	Intrap	Intrap	Intrap	—	—	—	—	Intrap	—	—
c-2	do	do	do	—	—	—	—	do	—	—
d-1	Intram	Intram	Intram	—	—	—	—	Intram	—	—
d-2	do	do	do	—	—	—	—	do	—	—
d-3	0	Subcut	Subcut	—	—	±	+	Subcut	±	+
d-4	0	do	do	—	—	±	—	do	±	—

and intramuscular vaccinations remained unchanged by the revaccination.

The result of this experiment appears to be quite instructive, showing that of the three organs tested the skin alone reacted by positive serologic reaction when it came in contact with the lifeless treponema antigen. Although the peritoneum and the muscles received more of the antigen than the skin they failed to respond. This entitles us to the conclusion that the skin tissue proper and not the lymphatic system nor the muscles is responsible for the production of the Wassermann reagin. The antigen reaches the mesenteric lymph glands from the peritoneum just as easy as it reaches the regional glands from the subcutis. Consequently if the lymph glands were the tissues that produce the Wassermann reagin the animals vaccinated by intraperitoneal injection would have given positive Wassermann reaction. This naturally does not prove that other organs, which were not considered in this experiment, are not concerned in the production of Wassermann reagin; but of the tissues that, after the subcutaneous vaccination with treponemas, come first into direct contact with the antigen the skin tissue proper is the one of greatest importance.

THE RELATION OF THE WASSERMANN AND THE KAHN REACTIONS WITH REGARD TO TREPONEMA ANTIGEN [1]

By Onofre Garcia

Of the Division of Biology and Serum Laboratory
Bureau of Science, Manila

As a complementary test to the Wassermann reaction the precipitation reactions have justified their use. In a large percentage of comparative tests performed by the two types of methods an agreement was found between the reactions mentioned. The disagreement between these reactions, that is to say, between the Wassermann reaction and the precipitation reactions, was encountered mostly in the early and in the late stage of treponematous diseases. It has been demonstrated that the precipitation reactions are found positive not only in syphilis but also in yaws.

During the experimental study of yaws in Philippine monkeys it has been shown that not only infection but also vaccination with killed treponemas produces positive Wassermann reaction.[2] It was thought opportune, during the study of experimental yaws in monkeys, to study the precipitation reactions, because little or no experimental work on these reactions has been done in the past. Furthermore, it was thought advisable to confirm by the precipitation reactions the serologic findings made by Wassermann reaction in yaws-infected or vaccinated monkeys. Of the several precipitation reactions in practice in the various parts of the world the Kahn reaction is the best known and most popular in America and it was therefore used in these experiments. Having infected and vaccinated monkeys at our disposal we have studied the Kahn reaction itself as it occurs in experimental animals and have compared the results obtained by this reaction with the results obtained by the Wassermann reaction.

[1] Received for publication, December 14, 1928.

[2] Schöbl, O., and B. Tanabe, antea 57; I. Miyao, antea 71 and 75.

TECHNIC

The technic followed in performing the precipitation test was the standard method of Kahn.[3] The serum of the experimental animals when separated, was centrifuged until it was perfectly clear; then it was inactivated at 56° C. for thirty minutes. The serums employed were not more than 24 hours old. Of the inactivated serum 0.15 cubic centimeter was added to each of the three test tubes containing, respectively, 0.05, 0.025, and 0.0125 cubic centimeter of the diluted antigen. The antigen was diluted in salt solution (0.85 per cent) in the proportion of 1.0 cubic centimeter Kahn antigen and 1.1 cubic centimeters of salt solution. The diluted antigen was allowed to stand at room temperature for fifteen minutes before the necessary amount of antigen was delivered into the test tubes. The tubes were placed in a rack and shaken by placing the rack on a table and pushing it to and fro with the hands. The shaking was continued for four minutes. After this 0.5 cubic centimeter of salt solution was added to each of the tubes containing 0.025 and 0.0125, respectively, and 1 cubic centimeter of salt solution was placed into the tube containing 0.05 cubic centimeter antigen. Reading was made immediately after shaking and another after two hours incubation at 37° C. The results of these two readings did not vary essentially, although the degree of precipitation and suspension of the precipitates were easier to read after two hours incubation than immediately after the addition of the salt solution.

Positive and negative serums as well as salt-solution controls were included in every Wassermann and Kahn test.

INTERPRETATION OF THE RESULTS OF THE KAHN TEST

The reading of the precipitates and the recording of plusses as resulted from the reading of the three test tubes were averaged according to the table given in Kahn's book. It deviates from the standard reading in cases in which precipitate was present in the third tube only (0.0125 cubic centimeter). Therefore the one plus; plus minus; one plus lens and plus minus lens can be interpreted as follows:

One plus; Fine precipitate easily detectable with the naked eye.
Plus minus: Very fine precipitate still detectable with the naked eye when carefully examined.

[3] Kahn, R. L., Serum Diagnosis of Syphilis by Precipitation; Governing Principles, Procedure and Clinical Application of the Kahn Precipitation Test. Williams and Wilkins Co.

One plus lens: Fine precipitate easily visible with the aid of a magnifying lens.

Plus minus lens: Precipitate still detectable when examined carefully with the lens but the precipiate is very fine.

Note: Negative-serum and salt-solution controls were always compared before a final reading was made.

With the knowledge gained by the experiments on the viability of Treponema framboesiæ,[4] an experiment was conducted to study the serologic changes produced in monkeys by vaccination with Treponema framboesiæ killed at various degrees of temperature.[5] Parallel Wassermann and Kahn tests were made in some of these animals. The results of the tests show that there was a fair agreement between the results of the Wassermann and the Kahn tests, but the Wassermann test shows a stronger reaction than the Kahn test, and the quantitative relation between the number of vaccinations and the strength of the reaction is not as evident in the Kahn as in the Wassermann test. Unfortunately the Kahn test was performed only in animals immunized by 80° C. and 100° C. yaws vaccine. The results would probably be different had the Kahn test been investigated in those monkeys which received unheated yaws vaccine or vaccine killed at 60° C. Nevertheless these results show that the antigen responsible for positive Kahn reaction is likewise thermostable as it was not destroyed by heating for one hour at 80° C. or 100° C. (see Table 1).

In the majority of the animals in the experiment [6] in which repeated injections of normal skin tissue or inflammatory skin tissue from normal or yaws-infected monkeys were used the result of the Kahn test was negative. There were two plus minus lens reactions obtained on the first examination which became negative on the second test. One of the seven animals gave repeatedly a frankly positive Kahn test (+ + + +). After the infection with yaws treponema the Kahn test shows again a close agreement with the Wassermann reaction, but it gives a positive result, sometimes earlier sometimes later than the Wassermann test. In two cases the Wassermann test became positive following infection while the Kahn test remained negative (see Table 3).

In connection with the question whether the skin tissue itself or other tissues are the principal organs in which the Wasser-

[4] Philip. Journ. Sci. 35 (1928) 333.

[5] Schöbl, O. and B. Tanabe, antea 57.

[6] Miyao, I., antea 71.

mann reagin [7] is produced, the Kahn test was also performed simultaneously with the Wassermann test. The result of this experiment shows that following subcutaneous vaccination, both Wassermann and Kahn reagin are produced exclusively by the skin proper and not by lymphatic or muscle tissue as shown by the serological results in vaccination as well as revaccination. It can be seen from the results in Table 2 that monkey d–3 gave the same result and even more pronounced with the Kahn test than by the Wassermann test, whereas monkey d–4 remained negative with regards to the Kahn test but weakly positive with the Wassermann test.

It is noteworthy as evident from Tables 2 and 3 that some normal monkeys showed slightly positive Kahn test where the Wassermann test was regularly negative. However, this slightly positive Kahn test in normal animals had obviously increased after vaccination or after infection as can be seen in animal d–3, Table 2; and in monkeys R–3 and a–2, Table 3. Therefore, this slight handicap of Kahn test with respect to Wassermann test as encountered in some of the known normal monkeys by no means invalidated the experimental findings. As a matter of fact monkey d–4 of Table 2 showed doubtful precipitation which never increased but remained negative in all subsequent tests made after vaccination and revaccination and after infection in animals a–1 and Z–2 (Table 3) which have been previously and respectively immunized with inflammatory skin tissue from a normal monkey and from a yaws monkey. This seemingly false precipitation in the Kahn test may be attributed to the inherent properties of some particular monkey's serums. In this experimental work these doubtful positive results of Kahn test or Wassermann reaction occasionally encountered in normal animals can be disregarded in view of the rise in titre of the serums following vaccination with yaws vaccine or infection with yaws.

CONCLUSIONS

1. The experimental infection with yaws produces in Philippine monkeys positive Kahn test.

2. Positive results by Kahn test were obtained in Philippine monkeys by immunization with dead treponemas killed at various degrees of temperature.

3. The treponema antigen which produces positive Kahn test when injected to suitable experimental animals is thermostable.

[7] Miyao, I., loc. cit.

4. It shows signs of specific antigen.

5. The treponema antigen which produces a positive Kahn test is most likely identical with that which produces positive Wassermann.

6. There is an agreement between the results of Wassermann and Kahn tests with regard to serologic reactivity of tissues to the injection of this antigen.

ACKNOWLEDGEMENT

I wish to express my sincere thanks to Dr. R. L. Kahn, of the Michigan Public Health Laboratory, for his courtesy in sending me the antigen which I obtained through the kind services of Dr. E. B. McKinley, member of the Rockefeller Foundation.

TABLE 1.—*Showing the results of Wassermann and Kahn tests performed on yaws-vaccinated monkeys.*

[—, complete hæmolysis; ±, less than 25 per cent inhibition; +, 25 per cent inhibition; ++, 50 per cent inhibition; +++, 75 per cent inhibition; ++++, 100 per cent inhibition; 0, not done. For interpretation of Kahn test see text.]

Designation of monkey.	Vaccination.						Vaccine killed 1 hour at—	After vaccination.			
	Number.	Date.	Number.	Date.	Number.	Date.		Wassermann reaction before vaccination.	Date.	Result of— Wassermann reaction.	Result of— Kahn test.
W-57	1	III- 5-28	2	III-12-28	3	III-20-28	80° C.	—	IV- 7-28	+++	0
									V- 3-28	++	+
									V-28-28	—	—
W-58	1	III- 5-28	2	III-12-28	3	III-20-28	80° C.	—	IV- 7-28	+++	0
									V- 3-28	+	±
									V-28-28	—	—
W-59	1	III- 5-28	2	III-12-28	0	----------	80° C.	—	IV- 7-28	++	0
									V- 3-28	+	+
									V-28-28	±	—
									VI-21-28	±	—
									VII- 6-28	—	—
									VII-18-28	—	—
W-60	1	III- 5-28	0	III-12-28	0	----------	80° C.	=	IV- 7-28	+	0
									V- 3-28	±	±
									V-28-28	±	—
W-61	1	III- 5-28	0	----------	0	----------	80° C.	—	IV- 4-28	—	0
									V- 3-28	+	—
									V-28-28	+	—
									VII- 6-28	—	—
									VII-18-28	—	—
									VII-30-28	—	—

W-63	1	III- 5-28	2	III-14-28	3	III-20-28	[a] 80° C.	—	IV- 7-28	—	0
									V- 3-28	±	±
									V-28-28	—	—
									VII-18-28	—	—
									IX-18-28	—	—
W-64	1	III- 5-28	2	III-14-28	3	III-20-28	[a] 80° C.	=	IV- 7-28	±	0
									V- 3-28	+	—
									V-28-28	—	—
									VII-18-28	—	—
									IX-18-28	—	—
K-9	1	IV-11-28	1	IV-16-28	1	IV-27-28	100° C.	—	V-17-28	+	±
A-8	1	IV-11-28	1	IV-16-28	1	IV-27-28	100° C.	—	V-17-28	+	±
J-18	1	IV-16-28	1	IV-27-28	0	----------	100° C.	—	V-17-28	++++	+++

[a] Diluted.

TABLE 2.—*Showing the serologic results after subcutaneous, intraperitoneal, and intramuscular vaccination against yaws. Both Wassermann and Kahn reactions considered.*

Designation of monkey.	Date and modus of vaccination.			Before vaccination, VI-13-28.	Wasserman reaction Results and dates. After vaccination			Revaccination, VIII-4-28.	Wasserman and Kahn reaction after revaccination.	
	First, VI-14-28	Second, VI-22-28.	Third, VI-30-28.		VII-13-28;	VII-27-28;	VIII-2-28.		Wasserman reaction, VIII-16-28.	Kahn reaction, VIII-30-28
c-1	Intrap.	Intrap.	Intrap.	— —	— —	— —	— —	Intrap.	— —	— —
c-2	do.	do.	do.	— —	— —	— —	— —	do.	— —	— —
d-1	Intram.	Intram.	Intram.	— —	— —	— —	— —	Intram.	— —	— —
d-2	do.	do.	do.	— —	— —	— —	— —	do.	— —	— —
d-3	0	Subcut.	Subcut.	— ±	— ++	± ++	+ ++++	Subcut.	± ++++	+ +++
d-4	0	do.	do.	— ±?	— —	± —	— —	do.	± —	— —

[a] The marks above are for Wassermann reaction. The marks below are for Kahn test.

TABLE 3.—*Showing the result of Wassermann reaction and of Kahn test in monkeys immunized with normal and inflammatory tissues from normal skin of normal and yaws monkeys.*

[—, complete hæmolysis; ±, less than 25 per cent inhibition; +, 25 per cent inhibition; ++, 50 per cent inhibition; +++, 75 per cent inhibition; ++++, 100 per cent inhibition; 0, not done. For interpretation of Kahn test see text.]

Designation of monkey.	Material used for subcutaneous vaccination.	Date and result of Wassermann and Kahn reactions after immunization.		Date and result of inoculation with yaws.	Date and result of Wassermann and Kahn reactions after infection and superinfection with yaws treponemas.							
R-3	Normal skin from normal monkey	VI-20-28	VII-5-28	VII-19-28	IX-3-28	IX-13-28	IX-27-28	X-10-28	X-23-28	X-31-28		
		[a]—	—	yaw	—	—	—	Dead	Dead	Dead	0	
		±1	—		±	+	++					
R-4	Do	VI-20-28	VII-5-28	VII-19-28	IX-3-28	IX-13-28	IX-27-28	X-10-28	X-23-28	X-31-28		
		—	—	yaw	—	—	—	—	+	—	0	
		—	—		± 1	±	+	—	+	+		
S-4	Normal skin tissue from yaws monkey	VI-20-28	VII-5-28	VIII-2-28	IX-3-28	IX-13-28	IX-27-28	X-10-28	X-23-28	X 31-28		
		—	—	yaw	—	—	—	—	+	—	0	
		—	—		—	—	—	—	∓	—		
A-1	Inflammatory skin tissues from normal monkey	VII-2-28	VII-16-28	VII-31-28	IX-3-28	IX-13-28	IX-27-28	X-10-28	X-23-28	X-31-28		
		—	—	yaw	—	++	—	—	+	±	0	
		—	—		—	—	—	—	—	—		
A-2	Do	VII-2-28	VII-16-28	VII-31-28	IX-3-28	IX-13-28	IX-27-28	X-10-28	X-23-28	X-31-28		
		—	—	yaw	—	+++	+	+++	++	+	0	
		+	++		++++	++++	++++	++++	+	∓		
Z-1	Inflammatory skin tissues from yaws monkey	VI-20-28	VII-5-28	VIII-2-28	IX-3-28	IX-13-28	IX-27-28	X-10-28	X-10-28	X-31-28	XI-14-28	XI-7-28
		—	—	yaw	—	—	—	—	—	—	±	—
		—	—		—	—	—	—	—	—	—	+
Z-2	Do	VI-20-28	VII-5-28	VIII-2-28	IX-3-28	IX-13-28	IX-27-28	X-10-28	X-10-28	X-31-28	XI-14-28	XII-7-28
		—	—	yaw	—	—	—	—	—	—	±	—
		± 1 ?	—		—	—	—	—	—	—	—	—

[a] The marks above are for Wassermann reaction. The marks below are for Kahn test.

SUMMARY OF SEROLOGIC STUDIES IN EXPERIMENTAL YAWS [1]

By Otto Schöbl

Chief, Division of Biology and Serum Laboratory
Bureau of Science, Manila

It appears from the experiments described in the preceding papers that the reagin of the Wassermann reaction is a true antibody of its kind. It occurs in the blood not only as a result of infection with treponemas but also as a result of subcutaneous injections of killed treponemas. It is therefore a direct serologic response to the antigen contained in the treponemas and not merely a consequence of interaction between the viable treponemas and the tissues. The "in vivo antigen" of the Wassermann reagin is a substance which can be liberated from the treponemas and which shows a high degree of thermostability and is specific. The same "in vivo antigen" that produces positive Wassermann reaction is responsible for the appearance of other serologic reactions which are based on the phenomenon of precipitation of the "in vitro antigen" by the serum of the tested subject (Kahn). The strength of the Wassermann reaction stands in direct proportion, but the pre-Wassermann period in inverse proportion, to the amount of the treponema antigen injected. The serologic response to repeated vaccination with killed treponemas is the same as the response to repeated infections interrupted by cures.

Following subcutaneous vaccination the skin proper and not the lymphatic tissues or the muscles are responsible for the production of the antibody detectable by the usual serologic reactions. Intraperitoneal and intramuscular vaccination failed to produce positive serologic reactions. The serologic reactions and the antitreponematous immunity are not directly dependent on each other but are dependent on a common factor that is the "in vivo antigen." Consequently these two phenomena show a certain parallelism. The strength of the Wassermann reaction in the early stage of the disease indicates the severity of the infection at that time, and therefore it indirectly prognosticates

[1] Received for publication, December 14, 1928.

the early development of the subsequent immunity. But the immunity continues to exist after the serologic reactions have vanished. However, the infection may be so mild that no appreciable serologic change will take place and yet immunity may set in even though delayed. If a persistent positive serologic reaction establish itself in the resistant stage of yaws following infection it may last for a long time without any apparent lesion or latent infection.

IMMUNOLOGIC RELATION BETWEEN YAWS AND SYPHILIS

By OTTO SCHÖBL and ISAO MIYAO *

Of the Division of Biology and Serum Laboratory
Bureau of Science, Manila

FOUR PLATES

The experiments performed on monkeys in the past with the view of studying the immunologic reciprocity between syphilis and yaws are open to serious criticism.

As few as they have been the experimenters, with the exception of Levaditi and Larier,[1] have convinced themselves that neither syphilis immunizes against yaws nor yaws against syphilis. The study of immunity in syphilis was stranded on the rock of "latent infection," and the field of immunity to yaws in monkeys, the most suitable experimental animals, lay idle for more than twenty years. A brief inspection of the experiments on monkeys as published in the early era of experimental syphilis will reveal to anyone that serious omissions have been made in the arrangement of the experiments.

1. There is little or no evidence afforded in these experiments that the viability of the material used for reinoculation was tested on normal control animals of the same kind.

2. There is no evidence afforded in the experiments that the disease first conveyed to the animals produced immunity to itself in the same animals before the immunity to the other disease was tested.

3. Neither the time factor in the development of immunity nor the quantitative degree of immunity was properly considered. It was apparently taken for granted that the syphilitic monkeys used in these experiments were immune to syphilis at the time they were inoculated with yaws because other syphilitic monkeys which were not used in the same experiments were found on other occasions to be immune to syphilis about that time after the first inoculation.

* Lieutenant Surgeon, Imperial Japanese Navy.

[1] Ann. de l'Inst. Pasteur 22 (1908) 263.

Furthermore, it was evidently taken for granted that the time necessary for the development of immunity to yaws is the same as that in syphilis.

Recent experiments[2] have shown that yaws monkeys (local yaw) were without exception inoculable with yaws for five months, after the first inoculation. During the sixth month a certain percentage of the animals was found resistant. Animals superinfected after the sixth month were without exception found to be immune. Yaws monkeys with generalized yaws were found immune earlier than those with local yaws, and in animals with late ulcerative forms the immunity was found much delayed. This shows quantitative degrees of immunity in experimental treponematoses a fact which has never been considered.

Therefore, the minimum time limit at which the majority of yaws monkeys can be reasonably expected to have developed a high degree of immunity to yaws is seven months after the date of successful inoculation, no less than two hundred ten days.

Equipped with this recently acquired knowledge with regard to immunity to yaws in monkeys we can see at a glance that the past experimental evidence on monkeys is reduced to one experiment on one monkey, the only experiment in which the interval between the inoculations was more than two hundred ten days (syphilis-yaws). This single case is not convincing in view of the fact that monkeys with late ulcerative yaws as a consequence of superinfection developed immunity late. One of them was successfully inoculable seventeen months after the original inoculation. The experiment of Levaditi and Larier, who were the only ones to conclude from their experiment the existence of cross immunity between syphilis and yaws, needs confirmation, particularly in view of the fact that only one test for immunity was made.

For the sake of clearness the results of previous experiments on monkeys as tabulated by Chesney (Table 1) are reproduced, together with our tabulated experiments on immunity to yaws in monkeys.[3]

With such meager experimental evidence on hand, concerning the cross immunity between yaws and syphilis, we have decided to attack the problem by experiments on Philippine monkeys.

[2] Schöbl, Philip. Journ. Sci. 35 (1928) 279–291.

[3] Philip. Journ. Sci. 35 (1928) 285, Table 10; 286, Tables 11 and 12.

Monkeys successfully inoculated with yaws more than twelve months previous to the test for cross immunity and which were proven to be immune to yaws were inoculated with syphilis.

BRIEF ACCOUNT OF THE STRAINS OF YAWS AND SYPHILIS USED IN CROSS-IMMUNITY EXPERIMENTS

THE STRAIN OF YAWS

The strain of yaws used in the experiments concerning the immunological relation between yaws and syphilis was the Philippine strain Kadangang named after the patient from whom it was isolated March 4, 1925. Since that time the strain has been passed from monkey to monkey. During this four-year period of continuous passages from monkey to monkey, no sign of attenuation has been noted, and at the time of writing the strain produces just as vigorous lesions as it did during the the first year after isolation from the patient. On Plate 1 is shown a yaws' lesion that appeared on the eyebrow and the nose of an experimental animal in consequence of superinfection with yaws. This local exacerbation was followed in time by numerous metastatic lesions as can be seen in Plate 2. We have selected this strain of yaws for our experiments because of its high virulence as well as our knowledge of the strain. One reads in the literature complaints of the difficulty of maintaining strains of yaws in rabbits. We have had no difficulty in maintaining yaws strains in monkeys. Apparently in this as well as in other respects the Philippine monkey is a far better experimental animal than the rabbit as far as yaws is concerned.

THE STRAIN OF SYPHILIS

The literature concerning syphilitic lesions produced experimentally in monkeys is fairly voluminous. However, the animals are designated without giving any information as to the locality from which they come. Most authors are satisfied with calling the monkeys macacus, cynomolgus, etc. It became necessary, therefore, for the study of syphilis with regard to immunity and its relation to yaws in Philippine monkeys to establish whether or not the animal experimented on is susceptible to syphilis, and the extent of the experimental syphilitic infection in this animal. There appears to be a general belief permeating the literature on experimental treponematoses that the suitability of an experimental animal is determined by its position

in the zoölogic system of classification. There is no evidence in the literature that a comparative study of treponematoses by appropriate experimental methods has ever been made, but the dogma as to the differences between higher apes and lower monkeys with regard to suitability for experimentation is perpetuated. As to yaws the experiments found in the literature, one on an orang-utan and a few isolated experiments on chimpanzees, contribute nothing more to our knowledge of the disease than the early experiments of Ashburn and Craig[5] on Philippine monkeys, and far less than our experiments by more appropriate procedure of experimentation on *Cynomolgus philippinensis*.[6] A a matter of fact the first animal ever successfully inoculated with syphilis was the rabbit. The confusion and misconception of immunity in experimental syphilis is not so much due to the unsuitability of the rabbit as an experimental animal as to the conventional method of experimentation and the interpretation of the results based on concepts of clinical traditions and on early theories of immunity. Indeed, the backbone of all this misconception, the theory of latent infection as a cause of resistance in treponematoses, was created as an explanation of experimental findings made on higher apes.

We believe that a good deal can be achieved in the advancement of our knowledge of these diseases by continuing to experiment on lower animals, without the fear that the disease may run a different course in an experimental animal than in man. The full possibilities of a given experimental animal must be discovered by appropriate methods of experimentation and the results obtained must be properly weighed without interference of past and present theories and traditions.

In these experiments we have chosen a well-known laboratory strain of syphilis. This was done for two reasons: First, that the objection may not be raised abroad that we have mistaken clinically yaws for syphilis, working as we are in a country where both diseases can be found, and that we isolated a strain of yaws believing it to be syphilis; and, second, because the strain of syphilis used by us is well known to laboratory men in the United States and Europe, and has been widely used in experiments on rabbits. Our findings, therefore, can be related to the results of others on other kinds of animals and may become more helpful in the interpretation of the infection and immunity in experimental syphilis.

[5] Philip. Journ. Sci. § B 2 (1907) 441–465.
[6] Philip. Journ. Sci. 35 (1928) 135.

Through the kindness of Col. J. F. Siler, United States Army Medical Corps, War Department, Washington, D. C., we were able to secure the well-known laboratory strain that was isolated by the late Lieutenant Colonel Nichols, United States Army. We wish to thank the Director and the staff of the Army Medical School Laboratories, Washington, D. C., for their courtesy in sending us rabbits inoculated with the Nichols strain of syphilis. Thanks are due to Major Simmons, Captain St. John, and Captain Reynolds, of the United States Army Medical Department Research Board, Manila, who were directly instrumental in the safe delivery of the Nichols strain.

The Nichols strain is well known to all who are engaged in the experimental study of syphilis and needs very little comment. It may be well, however, to mention for those who have not worked with this strain that it has been passed through numerous rabbits and that it produces 100 per cent takes in rabbits in the form of a typical syphilitic orchitis and chancre (Plate 3) with numerous treponemas in the lesions at a certain stage of the infection. The strain reached us in May, 1928, and immediately transfers were made to rabbits to assure the maintenance of the strain. Inoculations were performed on Philippine monkeys with the view to study the lesions that may be produced upon single inoculation with this strain in this kind of animals.

THE PROCEDURE OF INOCULATION OF MONKEYS

Using materials from the chancre or the orchitis of the syphilitic rabbit as a seed, we inoculated monkeys on the eyebrows and the scrotum, by intracutaneous injection. This was done particularly for the reason that the intracutaneous injection was used in our work with yaws and that it is a close approximation to the natural mode of infection with this disease in man. It yielded 100 per cent results. Some few monkeys were inoculated by intratesticular injection to test whether or not syphilitic infection in Philippine monkeys behaves similarly to that in rabbits in this respect.

THE PRIMARY SYPHILITIC LESION IN PHILIPPINE MONKEYS FOLLOWING INTRADERMAL INJECTION OF SYPHILITIC MATERIAL DERIVED FROM RABBITS INFECTED WITH NICHOLS STRAIN AND CONTAINING NUMEROUS TREPONEMAS LUIS

The first sign of the primary syphilitic lesion in Philippine monkeys is a slightly elevated superficial papule showing typical copper-colored discolorization on the light-colored skin of the

monkey's scrotum (Plate 4, fig. 1). This papule gradually becomes more and more elevated until a typical almost bluish-red papule develops at the place on the scrotum where the material was inoculated, as can be seen on Plate 4, fig. 2. The papule becomes elevated before it spreads out, is firm to the touch, and soon a deep induration at the base takes place. Upon incission of such a well-developed papule a clear serous fluid escapes. Whether left undisturbed or incised and scarified for the purpose of searching for treponemas the papule on the scrotum was never observed to develop a crust or an ulcer as observed in rabbits inoculated with the same strain of syphilis (Plate 3, fig. 2). In the course of further development this papule spreads into the depth of the skin with the induration and œdema surrounding it. The deep hard induration persists for varying lengths of time, and ultimately softens and disappears.

If the syphilitic material from the rabbit is injected subcutaneously a deep hard induration develops without the formation of a papule.

Inoculation on the eyebrows never produced a typical papule as observed on the scrotum, but a hard induration evidently involving all layers of the skin. Superficial ulcerations were sometimes observed on the eyebrows, never on the scrotum.

The few instances in which Philippine monkeys were inoculated with syphilitic material containing treponemas by intratesticular inoculation gave at times a slight induration of the testis, but a typical orchitis as we are accustomed to find in rabbits or a chancre on the scrotal skin was never observed (Plate 3, figs. 1 and 2).

The lesions so far described arose as a consequence of single inoculations of Philippine monkeys with syphilitic material. They were characterized by the fact that only occasionally treponemas were found within the lesions and then in much smaller numbers than regularly found in a yaws lesion in the same kind of animal.

INCUBATION AND DURATION OF INITIAL SYPHILITIC LESION IN PHILIPPINE MONKEYS

The average incubation period, that is, the time between the inoculation and the first appearance of a suspicious lesion, was approximately three weeks. However, the lesion sometimes was noticed earlier (two weeks) and sometimes later (four and a half weeks). The duration of the hard deep infiltration lasted

at times for several weeks, as long as twelve weeks. After this length of time the lesion was no longer perceptible by palpation. When the lesion healed, there being no ulceration, it healed without any trace whatsoever on the skin. Not infrequently the initial papule healed without developing further. From this observation on more than twenty Philippine monkeys it can be concluded that the Philippine monkey is not a very promising animal for syphilis experimentation, yet a definite, local, clinically characteristic lesion develops in this animal. Since the treponemas in the primary lesion are few and only occasionally found, it would be difficult to judge the result of immunization and of immunity to syphilis in these animals by the character or extent of the local lesion alone. Another sign of infection had to be looked for to enable us to interpret the findings of the infection as a test for immunity. It is well known that Treponema luis survives in the popliteal gland in syphilitic rabbits for considerable time after the local lesion has healed. It was, therefore, of importance to decide the question whether in Philippine monkeys Treponema luis remains at the place of inoculation or invades other body tissues. It was decided to search for the treponemas in the lymphatic glands corresponding to the initial lesion. The duration of the lesion was on the average five weeks, the longest eight, and the shortest two weeks.

INVESTIGATION CONCERNING THE SURVIVAL OF TREPONEMA LUIS IN THE INGUINAL LYMPH GLAND OF PHILIPPINE MONKEYS CORRESPONDING TO THE PRIMARY LESION OR POINT OF INOCULATION WITH VIRULENT TREPONEMA LUIS

The procedure used in this investigation was as follows:

At various intervals of time after the healing of the initial lesion the inguinal lymph gland corresponding to the side of the scrotum where Treponema luis was injected was surgically removed, triturated in a sterile mortar, suspended in a small amount of salt solution, and injected intratesticularly into male rabbits. The results are given in Table 1.

This table shows that five of five normal control monkeys inoculated with syphilis by intracutaneous injection of syphilitic material harbored viable Treponema luis in the inguinal gland corresponding to the place of inoculation on the scrotum. Another monkey inoculated with the same strain of syphilis but by intratesticular injection also harbored the treponemas in the regional lymph gland. The lymphadenectomy in these animals

was made two, three, four, and five months after the inoculation. The experimental syphilitic skin lesions in these monkeys were of various intensities. Treponemas could be found in but few of the lesions; the search by microscope in the greater number of them failed to reveal treponemas. Contrary to the findings in yaws lesions of monkeys the treponemas found in the syphilitic initial scrotal lesion of the same kind of animals were very few if found at all. In spite of that Treponema luis reached the lymph gland with great regularity and survived there long after the lesion had healed. For comparison and for the convenience of the reader we reproduce the table from a previous publication which shows the results of lymph-gland transplants from yaws-infected monkeys to normal monkeys.[7]

CONCLUSIONS DRAWN FROM PRELIMINARY EXPERIMENTS CONCERNING SYPHILITIC INFECTION IN PHILIPPINE MONKEYS

1. Contrary to the claim in the literature[8] Philippine monkeys, *Cynomolgus philippinensis,* are susceptible to syphilis (Nichols strain).
2. The syphilitic lesion produced by single experimental inoculation using the intracutaneous injection on the scrotum is a typical copper-colored papule with indurated base. It may heal at this stage or progress to a sclerosis.
3. A chancre was never observed to develop on the scrotum in Philippine monkeys either by intradermal or intratesticular inoculation with the Nichols strain, which, as is well known, produces typical syphilitic orchitis and chancre in rabbits as a consequence of intratesticular inoculation (Plate 3).
4. On the eyebrows hard induration developed consequent to the intradermal inoculation with the Nichols strain of syphilis. At times flat shallow defects were observed which sometimes contained a good number of treponemas.
5. The incubation of the lesions thus produced averaged three weeks, the shortest was two weeks, and the longest four and a half weeks.

THE NATURE OF IMMUNITY IN TREPONEMATOSES

Whether stress is laid on phagocytosis, agglutination, bacteriolysis, or other demonstrable phenomena of immunity the

[7] Philip. Journ. Sci. 35 (1928) 302, Table 17.

[8] Phehn, Ueber den gegenwärtigen Stand der Framboesie-Frage, Beih. z. Archiv für Schiffs- und Tropen-Hygiene 16 (1912) 321.

traditional and prevailing concept of immunity is that of curative immunity. The bacteria are immobilized, dissolved outside or inside of leucocytes not only in vitro but also in vivo. These are the original theories of immunity and defense against infections. However, the painstaking experiments of Oskar Bail, Edmund Weil, and others of their school showed that resistance can be induced by immunization with sterile exudates produced by mass infection with virulent bacteria of septicæmic proclivities. Thus achieved immunity localizes the infection at the places of inoculation and prevents the growth of bacteria as well as the invasion of body tissues by the infectious agent without injuring its viability or virulence. Further advancement in immunology was made by v. Pirquet's investigations on allergy. The last two steps in the progress of our knowledge of bacterial immunity led to our concept of immunity in treponematoses.[9]

As we have pointed out, there exists a fairly constant and direct[10] relation between the vigor of early yaws lesions and the number of treponemas found therein. The resistance of the body tissues, which is apparent by a partial or complete inhibition of development of early yaws lesions, prevents the growth and multiplication of the treponemas at the point of intradermal inoculation. The treponemas do not multiply sufficiently to invade the lymphatic system, consequently they never reach the blood stream. The development of a local initial lesion is prevented by this condition and the generalized infection is made impossible. This statement refers to the cutaneous portal of infection and not to intravenous inoculation of treponemas, an artificial condition by which the main barriers of defense, the skin and the lymphatic system, are set aside and only the end part of the whole process of infection is imitated. Likewise the intratesticular inoculation, as useful a laboratory method as it is, cannot be accepted as an approximation, in an experiment, of the way in which man acquires syphilis except under most extraordinary circumstances. Bearing in mind the law of sequence of Brown and Pierce we may fear different conditions with regard to immunity in animals, inoculated by the intratesticular method, from the immunity which develops as a consequence of an infection through the natural portal in

[9] Philip. Journ. Sci. 35 (1928) 279–297.
[10] Philip. Journ. Sci. 35 (1928) 257.

man, that is the integument. The frequent occurrence in a rabbit inoculated with syphilis by intratesticular injection that orchitis develops long before a chancre hints at a reverse sequence in pathogenesis of experimental syphilis under such artificial conditions. Lesions develop in an internal organ prior to those on the integument in such a case.

When Treponema framboesiæ has reached the lymphatics, and after the skin lesions of the monkey have healed, it does not survive there or in tissues other than the skin for a sufficiently long time to maintain the infection. This has been demonstrated in monkeys.[11] In syphilitic monkeys, as in rabbits, Treponema luis reaches the lymph glands regularly and survives there long after the lesion has healed not withstanding the insignificant local syphilitic skin lesions that develop in Philippine monkeys as compared with the intensive and extensive yaws lesions in the same kind of experimental animal. This is the fundamental biologic difference between the two treponemas, and it serves as a rational explanation of the clinical differences between yaws and syphilis with reference to lesions in internal organs, the central nervous system, the cardiovascular system, and consequent to the latter the difference in congenital transmission of the two diseases, all of which manifestations are found in syphilis but are absent from yaws.

To test the truth of this concept deduced from our early studies of experimental yaws which prompted us to state on another occasion that immunity in treponematoses resembles antiaggresin immunity, and to corroborate our findings on syphilitic skin lesions in nonimmune and yaws-immune monkeys we have undertaken the following experiment.

We selected a group of thirteen monkeys which had gone through yaws infection, developed local yaw, healed long ago, and had been found repeatedly immune to yaws. In the test for immunity to yaws these monkeys gave negative results while normal control animals inoculated with the same material at the same time developed yaws at the places of inoculation. The thirteen monkeys thus found to be immune to yaws were inoculated by intradermal injection of syphilitic material secured from a rabbit. Another group of five normal monkeys was also inoculated at different times in the same way with the same strain of syphilis.

[11] Philip. Journ. Sci. 35 (1928) 257.

The differences in size, character, and duration of the syphilitic lesions in the animals immune to yaws as a consequence of local yaw produced years ago, and the syphilitic lesions which resulted as a consequence of inoculation into nonimmune normal control monkeys were quite marked. The yaws-immune animals developed small short-lived lesions resembling luctin reaction, or no lesions.

Treponemas were not found microscopically in the abortive syphilitic lesions which developed in yaws-immune animals. However, they were not found regularly by microscopic examination in typical syphilitic lesions of nonimmune monkeys. Furthermore, the objection may be raised that the reading of the resulting lesions may be subject to personal equation. Another corroborative and more-convincing method had to be resorted to.

Consequently search was made for viable Treponema luis in the lymph glands corresponding to the place of inoculation with syphilis. Monkeys immune to yaws due to infection, and nonimmune monkeys were included. Transplants of the lymph glands by intratesticular injection to the rabbits were made some time after the local syphilitic lesions in the nonimmune control monkeys had healed. Two rabbits were inoculated with the lymph glands from each monkey so as to safeguard against untimely death of the rabbits. The greatest part of the rabbits were observed for five months or more. It can be seen from Table 2 that every one of the control animals harbored viable Treponema luis in the lymph glands after the initial syphilitic lesion healed. It is further shown that none of the thirteen yaws-immune monkeys contained Treponema luis in the lymph glands at any time after the intracutaneous infection with syphilis. There was a striking difference in size, color, and consistency of the lymph glands in the yaws-immune and the control monkeys. The lymph glands in the immune animals had a normal appearance while those in the control monkeys were large, firm, and grayish.

DISCUSSION

In yaws as in syphilis coincident immunity and infection exist, but in experimental framboesia the treponemas do not survive in the lymphatic system after the lesions have healed as they do in syphilis. Consequently, in yaws some time after healing the infection ceases to exist and the immunity persists.

The presence of treponemas in the lymph glands is rightfully considered as an indication of a tendency of the infection to become generalized. In experimental syphilis it appears to be a more constant condition than in yaws. However, it cannot be taken as an indication of the degree of subsequent immunity. In experimental local yaws viable treponemas may or may not be demonstrable in the lymph gland corresponding to an active yaws lesion, but whether or not treponemas are present in the lymph gland the time necessary for the development of immunity is the same. The generalized skin manifestations of yaws infection, on the contrary, serve as a reliable sign of an early onset of high-grade immunity. Evidently the lymphatics do not participate to such an extent as the skin in building up immunity in yaws. This immunity is not treponemocidal and the survival of Treponema luis in the lypmh glands is a phenomenon of its biologic property which Treponema framboesiæ lacks. In spite of the long persistence of Treponema luis in the lymph glands of rabbits or monkeys after the initial lesion has healed, the animals are immune to super- or reinoculation and no relapses of clinical manifestations take place.

Following an inoculation with syphilitic material the treponemas reach the lymph gland and other tissues before the initial lesion has healed and long before the immunity has developed. When immunity develops it does not destroy the treponemas but keeps them at bay wherever they are found at that time. When immunity in our experimental animals was fully established by yaws infection prior to inoculation with syphilis Treponema luis never reached the lymph glands nor even multiplied at the point of inoculation. Consequently syphilitic initial lesions failed to developed in the skin of yaws-immune monkeys, or only a short-lived, feeble swelling developed which resembled the efflorescence seen in positive luetin reaction or the immunity reaction following inoculation with yaws performed in yaws-immune monkeys. The treponemas were prevented from multiplication at the point of inoculation and never reached the first lymph glands.

The evidence derived from the experiments herein presented augments our knowledge of the fundamental principles underlying the treponematous infections. It confirms our supposition concerning immunity in treponematoses. These fundamentals should always be borne in mind whenever an interpretation of any phenomenon or manifestation in the course of these diseases is attempted.

Thus far in our investigations the fundamental facts and principles are:

1. The treponema of syphilis is far more resistent to adverse conditions prevailing outside the tissues of the host than the treponema of yaws.

2. The treponema of syphilis is panblastotropic. It can invade, multiply, and colonize all tissues. It does that with a mesoblastic preference, and according to the law of sequence. It survives and produces lesions in the various tissues. The consequence is syphilitic manifestations on the skin, the mucous membranes, the internal organs, and the nervous tissue. Treponemas of syphilis invade the cardiovascular system and consequently the placenta, resulting in congenital syphilis.

The treponema of yaws is epiblastotropic. It invades, colonizes, and produces lesions only in certain tissues, particularly the skin. Its invasion may extend to mucous membranes by extension per continuitatem from the skin. It lacks the mesodermic preference of the treponema of syphilis. Consequently the internal organs, the nervous tissue, and the cardiovascular system remain unaffected and the disease is not congenital.

3. Immunity exists in treponematous infections and its mechanism is the same as that of antiaggressive immunity found in certain bacterial infections. It localizes the infection and keeps

TABLE 1.—*Showing the results of cross inoculation of monkeys with yaws and syphilis.*

[Tabulated by Alan Mason Chesney, Medicine Monographs Immunity in Syphilis Vol. 12:63.]

Author.	Animal.	First inoculation.	Incubation period.	Interval between inoculations.	Second inoculation.	Result.	Incubation period.
			Days.	*Days.*			
Neisser, Baermann and Halberstadter.	Mac. cyn	Yaws	46	32	Syphilis	Positive	21
	Mac. nig	Syphilis	26	41	Yaws	Positive	34
Halberstadter	Mac. cyn	Yaws	49	73	Syphilis	Positive	22
	Mac. nem	Syphilis	36	296	Yaws	Positive	46
	Mac. cyn	Syphilis	52	58	Yaws	Positive	42
Castellani	Mac. pil	Yaws	?	(a)	Syphilis	Positive	26
	Mac. cyn	Yaws	32	101	Syphilis	Positive	42
Levaditi and Nattan-Larier.	Mac. rhes	Syphilis	15	74	Yaws	Negative	
	Mac. cyn	Syphilis	20	91	Yaws	Negative	
	Mac. cyn	Syphilis	22	91	Yaws	Negative	
	Mac. rhes	Syphilis	19	95	Yaws	Negative	
	Bon. chin	Syphilis	28	110	Yaws	Negative	

[a] About 136 days.

the treponemas wherever they happen to be at the time of the onset of immunity. The immunity prevents the treponemas from further invading the tissues without injuring their viability or virulence. The tissues may at times react excessively in the attempt to suppress the invader. Late so-called tertiary lesions are the result thereof. Quantitative degrees of immunity exist.

4. Biologic healing of the lesions is independent of the immunity. There are reliable signs indicating that leucocytes play an important part in the destruction of treponemas and consequently in the spontaneous healing of lesions.

TABLE 10.—*Showing the development of immunity in yaws-infected Philippine monkeys.*

(Philippine Journal of Science, Vol. 35, No. 3, March, 1928, p. 285.)

[—, negative take; +, positive take; ±, feeble take.]

Monkey No.	Months after original inoculation.													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
L-6	+													
M-5	+													
T-4	+													
J-13	+													
A-5		+												
D-10		+												
G-7		+		+	±	—								
F-13		+		+										
E-13		+				+								
K-3		+												
L-5		+												
K-2			+		+		—		—					
B-1			+			+				—		—		
B-2			+			+				—		—		
B-3			+				—		—					
H-17				+		—								
J-11				+		—								
F-12				+		—								
C-2				+		—								
P-10				+				—	—	—				
M				+										
S-b				+			—							
O-b						—		—						
F-11						—								
M-3						—		—						
M-2						—								
A-3							—					—		
D-9							—		—					
A-2								—		—		—		—
H-16-b								—		—				
D-8											—		—	
L-4												—		—

TABLE 11.—*Showing the development of immunity in monkeys with generalized yaws.*

(Philippine Journal of Science, Vol. 35, No. 3, March, 1928, p. 286.)

[+, positive take after superinfection; —, negative take after superinfection; exac, exacerbation; gen, generalization; reg. met, regional metastases.]

Monkey No.	Result of first inoculation	Months after original inoculation.																			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
P-8	Initial local yaw				+	gen			—												
N-8	do		exac	reg. met	gen		—			—											
T-1	do	+		exac	—, gen			—													
G-6	do		+—, exac	—, gen	—																
C-3	do				+	exac gen	—														
E-15	do	+			exac	gen			—												

[a] The symbols are placed in the months in which the superinfection, the exacerbations, or the generalization took place.

TABLE 12.—*Showing the development of immunity in monkeys with late ulcerative lesions.*

(Philippine Journal of Science, Vol. 35, No. 3, March, 1928, p. 286.)

[+, positive take; ±, feeble take; —, negative take.]

Monkey No.	Result of first inoculation.	Months after original inoculation.																			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
C-1	Initial local yaw	+														+, ulcer				±	
J-10	do				+, ulcer						±										
H-18	do		+		+, ulcer	—															

TABLE 17.—*Showing the results of lymph gland inoculation in Philippine monkeys.*

(Philippine Journal of Science, Vol. 35, No. 3, March, 1928, p. 302.)

[+, positive; —, negative; tr., treated with neosalvarsan.]

Recipient monkey.	Lesion.			Treponemas in lesion.	Result.		Donor monkey.
	Active.	Healing.	Healed.		Microscopic.	Take.	
R-2	+	—	—	+	—	—	T-13
R-2	+	—	—	+	—	—	Y-2
R-2	+	—	—	+	—	—	H-21
K-7	+	—	—	+	—	+	J-15.
A-6	+	+	—	+	—	+	B-5
P-14	+	—	—	+	—	—	A-7
N-15	+	+	—	+	—	—	B-5
L-7	—	+	—	+	—	+	G-9
Y-5	+	+	—	+	—	—	A-6
Y-5	+	—	—	+	—	—	O-d
Y-5	—	—	+	—	—	—	B-6
Y-4	—	—	+	—	—	—	P-13
Y-4	—	—	+	—	—	—	A-7
Y-4	+	—	—	+	—	—	G-10
Y-6	+ late	+	—	—	—	—	H-18
Y-6	+ tr	—	—	+	—	—	Baby I
Y-3	—	—	+ tr	—	—	—	B-K-3
Y-3	—	—	+ tr	—	—	—	B-K-2

TABLE 2.—*Showing the results of inoculations with syphilis performed on normal monkeys. The results of tests for the presence of viable treponema of syphilis in the lymph glands is also shown.*

[+, typical lesion; —, no lesion. The months are indicated by roman numerals, the days and years by arabic figures.]

Designation of monkeys.	Infected with syphilis.	Appearance of syphilitic lesion.	Lymph gland inoculation to rabbit.		Remarks.
			Date.	Result.	
Sy-1	V-16-28	+ VI-19-28	IX- 8-28	+	Intracut.
Sy-3	VI-13-28	+ VI-26-28	IX- 8-28	+	Intracut.
Sy-2	V-24-28		X-22-28	+	Intratest.
Sy-5	VI-15-28	+ VI-26-28	X-22-28	+	Intracut.
Sy-6	VI-15-28	+ VI-26-28	X-22-28	+	Intracut.
K-11	IX-13-28	+ X- 3-28	XI-12-28	+	Intracut.

SUMMARY

Philippine monkeys that have gone through yaws infection produced by the Kadangan strain and found immune to yaws by repeated inoculations with homologous strain were found immune to cutaneous inoculation with the Nichols strain of syphilis.

CONCLUSIONS

A high degree of immunity to yaws protects against cutaneous infection with syphilis in Philippine monkeys.

TABLE 3.—*Showing the results of inoculations with syphilis performed on yaws-immune monkeys. The results of the tests for the presence of viable treponema of syphilis in the lymph glands are also recorded.*

[+, typical lesion; ±, immunity reaction; —, no lesion.]

Designation of monkey.	Infected with yaws.		Infected with syphilis.		Lymph gland transplants.		Rabbit.	
	Date.	Result.	Date.	Result.	Date.	Result.	Lived May 15, 1929.	Died.
J-11	III-19-26	+	VI-15-28	±	XI-19-28	—	one	I-14-29 one
	VII- 6-26	+						
	IX-29-26	—						
	IV- 4-27	—						
	III-26-28	—						
	I-11-29	—						
L-5	VII-16-26	+	IX-13-28	—	XI-16-28	—	one	II-11-29 one
	IX-29-26	+						
	III- 8-27	—						
	III-26-28	—						
L-6	XI-15-26	+	VIII-31-28	—	X-24-28	—	two	
	XII-27-26	+						
	VII-20-27	—						
	III-26-28	—						
D-8	IV-25-25	+	VI-15-28	±	XI-12-28	—	two	
	III-15-26	—						
	V-14-26	—						
	IV- 4-27	—						
	II- 4-28	—						
	I-11-29	—						
O-c	VII-27-26	+	IX-13-28	±	XI-16-28	—		XII-12-28 XII-10-28
	IV- 4-27	—						
	III-26-28	—						
	I- 8-29	—						

TABLE 3.—*Showing the results of inoculations with syphilis performed on yaws-immune monkeys. The results of the tests for the presence of viable treponema of syphilis in the lymph glands are also recorded*—Continued.

[+, typical lesion; ±, immunity reaction; —, no lesion.]

Designation of monkey.	Infected with yaws.		Infected with syphilis.		Lymph gland transplants.		Rabbit.	
	Date.	Result.	Date.	Result.	Date.	Result.	Lived May 15, 1929.	Died.
J-16	XI-5-26	+	VIII-31-28	—	XI-19-28	—	------	XI-20-28 I-21-29
	XII-27-26 Treatment; 0.08 gms neosalvarsan.	------	------	------	------	------	------	
	VII-18-27	+	------	------	------	------	------	
	III-26-28	—	------	------	------	------	------	
T-4	VII- 2-26	+	IX-13-28	—	XI-16-28	—	------	XII- 3-28 XII-10-28
	VIII-20-26	+	------	------	------	------	------	
	III- 8-27	—	------	------	------	------	------	
	III-26-28	—	------	------	------	------	------	
	I- 8-29	—	------	------	------	------	------	
K-7	I-15-27	+	VI-15-28	—	XI-12-28	—	two	
	III-26-28	—	------	------	------	------	------	
	XII-28-28	—	------	------	------	------	------	
Y-4	V-31-27	+	VIII-30-28	±	X-24-28	—	two	
	III-27-28	—	------	------	------	------	------	
	XII-28-28	—	------	------	------	------	------	
B-6	IV-12-27	+	VIII-30-28	—	XI-12-28	—	two	
	I-24-28	—	------	------	------	------	------	
	XII-28-28	—	------	------	------	------	------	
J-15	XI- 5-26	+	VIII-31-28	—	XI- 9-28	—	------	XII-10-28 XII- 3-28
	XII-22-27	—	------	------	------	------	------	
	III-26-28	—	------	------	------	------	------	
A-6	I- 6-27	+	VIII-31-28	±	XI-19-28	—	two	
	III-15-27	+	------	------	------	------	------	
	I-23-28	—	------	------	------	------	------	
	IV-11-28	—	------	------	------	------	------	
H-20	XI- 8-26	+	VIII-31-28	—	X-24-28	—	two	
	XII-27-26	+	------	------	------	------	------	
	III-26-28	—	------	------	------	------	------	
	I- 8-29	—	------	------	------	------	------	

ILLUSTRATIONS

Plate 1

Showing an extensive and intensive local yaws lesion. The lesion was produced with a strain of yaws (Cadangan) that has been passed through monkeys exclusively for four years.

Plate 2

Showing multiple metastatic yaws lesions produced in Philippine monkey with a strain of yaws (Cadangan) that has been passed through monkeys exclusively for four years.

Plate 3

Showing typical syphilitic lesions produced in rabbits with Nichols strain of syphilis.

Fig. 1. Orchitis.
2. Bilateral orchitis and chancre on the left side of the scrotum.

Plate 4

Showing initial syphilitic lesion in Philippine monkey produced by intradermal injection of syphilitic material (Nichol's strain).

Fig. 1. Initial papule on the left side of scrotum.
2. Fully developed sclerosis on the left side of the scrotum surrounded by deep œdema of the skin.

PLATE 1.

PLATE 2.

1

2

PLATE 3.

1

2

PLATE 4.

NEW ARCHIPELAGIC MEMBRACIDÆ

By W. D. Funkhouser

Of the University of Kentucky, Lexington

TWO PLATES

Through the courtesy of Mr. R. C. McGregor, of the Philippine Bureau of Science, the writer has been permitted to examine from time to time a considerable number of specimens of Membracidæ from the Philippine Islands. From this material and from specimens which have been received from other parts of the Archipelago, the following new species may be described:

PYRGONOTA SINUATA sp. nov. Plate 1, fig. 1.

Large, brown, pubescent, punctate; pronotal horn long, heavy, sinuate, ridged, bifurcate at tip; posterior process long, slender, sinuate, without lateral carina, extending to internal angle of tegmina; tegmina brown, opaque, with small hyaline spot just before internal angle, basal and costal margin finely punctate; sides of thorax densely white tomentose; legs entirely lemon yellow.

Head obovate, longer than broad, roughly sculptured, finely punctate, sparingly pubescent, with long silky hairs which are white on median line and on clypeus; base strongly sinuate; eyes large, mottled brown and yellow; ocelli large, yellow, twice as far from each other as from the eyes and situated about on a line drawn through centers of eyes; clypeus broad, flat, extending for half its length below lateral margins of genæ and continuing the outline of the genæ, tip rounded and pilose.

Pronotum brown, coarsely punctate, sparingly pubescent with coarse, white hairs; humeral angles weak, not prominent; median carina percurrent; pronotal horns heavy, sinuate, longer than the rest of the body, extending forward and upward, lateral surfaces irregularly carinate, tip bifurcate with each prong again bifurcate; posterior process long, slender, sinuate, lateral areas not carinate, extending just to internal angles of tegmina, tip acute; scutellum very little exposed; inferior lateral margins of thorax toothed.

Tegmina opaque, brown, narrow, pointed; basal and costal areas finely punctate; veins heavy and not pilose; small hyaline spot at inner margin just before internal angle.

Sides of thorax and lateral bases of pronotum densely white tomentose; undersurface of abdomen brown with white pubescence.

Coxæ, trochanters, femora, tibiæ, and tarsi uniformly lemon. yellow; claws brown; first two pairs of tibiæ flattened.

Length from front of head to tips of tegmina, 9.5 millimeters; length of pronotal horn from humeral angle to tip, 12; width between humeral angles, 2.5.

Type, female.

Type locality, Ripang, northern Luzon, Philippine Islands.

Described from a single specimen secured from Staudinger-Bang-Haas and now in the author's collection.

HYPSAUCHENIA RECURVA sp. nov. Plate 1, fig. 2.

Small, brown, with yellow markings, punctate not pubescent; pronotal horn strongly recurved, bifurcate at tip, prongs flattened; posterior process heavy, a high conical elevation on dorsal margin; tegmina opaque, brown with a hyaline fascia at internal angle; area between pronotal horn and dorsal protuberance yellow; legs yellow-brown.

Head subtriangular, longer than broad, roughly sculptured, finely punctate, not pubescent, brown; base arcuately sinuate; eyes large, dark brown; ocelli large, elevated, yellowish, more than twice as far from each other as from the eyes and situated above a line drawn through centers of eyes; clypeus twice as long as wide, extending for two-thirds its length below inferior margins of genæ, tip rounded and blunt.

Pronotum brown with yellow carinæ, punctate, not pubescent; humeral angles rounded, blunt; median carina percurrent; a sharp yellow carina on each side median line on pronotum extending from above eyes to base of pronotal horn; pronotal horn long, slender, strongly curved backwards, suddenly concave before tip, tip bifurcate, the prongs flattened dorsoventrally, reaching to a point above the base of the posterior elevation; posterior process heavy, base yellow, bearing in middle of dorsal margin a large conical elevation, tip acute and reaching just to internal angle of tegmina; scutellum well exposed.

Tegmina opaque, brown; basal and lateral margins strongly and finely punctate; tip pointed; a large subrectangular hyaline spot at internal angle; veins not prominent, not pilose.

Sides of thorax and undersurface of body brown with irregular yellow fascia; inferior margins of thorax toothed; legs luteous-brown.

Length from front of head to tips of tegmina, 7 millimeters; width between humeral angles, 2.

Type, female.

Type locality, Roban, Java.

Described from two females in author's collection.

CENTROCHARES FOLIATUS sp. nov. Plate 1, fig. 3.

Large, black, very spiny, roughly punctate, not pubescent; pronotal horns slender with broadly foliaceous protuberance just before tip, tip acute and just reaching tips of tegmina; tegmina opaque, black, with internal apical area translucent brown; legs dark brown.

Head subtriangular, longer than wide, black, finely punctate, not pubescent, roughly sculptured, median depression deep between ocelli; base arcuate, feebly sinuate; eyes large, black, margined with brown; ocelli large, prominent, elevated, pearly, twice as far from each other as from the eyes and situated well above a line drawn through centers of eyes; clypeus twice as long as wide, extending for two-thirds its length below inferior margins of genæ, tip rounded and blunt.

Pronotum black, punctate, roughly spined, not pubescent; humeral angles large, prominent; metopidium about as wide as high, arcuate; median carina roughly percurrent; pronotal horns arising from behind and above humeral angles, extending outward and upward, slender for half their length, upper half swollen to form a broadly foliaceous tip, this tip subquadrate, roughly sculptured and carinate above, smooth below with a single carina, extremity suddenly acute; posterior process heavy, sinuate, the middle elevation consisting of a median dorsal and two lateral foliaceous protuberances, tip sharp and extending just to tips of tegmina; scutellum entirely exposed, bifid at tip.

Tegmina opaque, black, except at internal apical margin, which is translucent dark brown; basal and costal area strongly punctate; veins heavy, prominent, black; five apical cells.

Sides of thorax and undersurface of abdomen uniformly black; legs dark brown; all tibiæ foliaceous.

Length from front of head to tips of tegmina, 5.4 millimeters; width between tips of pronotal horns, 5.

Type, female.

Type locality, Mowong, West Borneo.

Described fron a single specimen. Type in author's collection.

CRYPTASPIDIA AURICULATA sp. nov. Plate 1, figs. 4 and 5.

Large, black, finely punctate, finely pubescent; humeral angles projected to form auricular horns; no suprahumeral horns; posterior process heavy, tectiform, acute, extending just beyond internal angles of tegmina; tegmina vinaceous, subhyaline, base black and punctate; undersurface of body black; legs dark brown.

Head subquadrate, wider than long, black, finely punctate, feebly pubescent; base arcuate; eyes large, brown; ocelli small, inconspicuous, pearly, farther from each other than from the eyes; clypeus twice as long as wide, extending for half its length below inferior margins of genæ, tip broad, truncate, pilose.

Pronotum black, finely punctate, finely pubescent; metopidium sloping, broader than high; humeral angles produced to form auricular projections, extending outward and slightly upward, about as long as half the distance between their bases, tips rounded; median carina faintly percurrent; posterior process heavy, tectiform, black, tip acute and reaching just beyond internal angle of tegmina; scutellum not exposed.

Tegmina smoky vinaceous hyaline; base coriaceous black and punctate; veins heavy, brown, not pilose.

Sides of thorax and undersurface of body black; legs very dark brown.

Length from front of head to tips of tegmina, 7 millimeters; width between tips of humeral extensions, 5.

Type, female.

Type locality, Ubi, Laguna Province, Luzon, Philippine Islands (*R. C. McGregor*), July, 1926.

This species suggests *Tricentrus auritus* Buckton, but the horns are extensions of the humeral angles and not supra humerals.

CRYPTASPIDIA LUSTRA sp. nov. Plate 1, fig. 6.

Large, black, shining, polished, faintly punctate at margin of pronotum, not pubescent; no suprahumerals; scutellum not exposed; posterior process reaching well beyond internal angles of tegmina; tegmina smoky hyaline with base black, a brown fascia across middle and a brown spot before apex; undersurface of body black; legs black marked with brown.

Head black, convex, twice as long as wide, longitudinally striate, not pubescent, not punctate, base regularly sinuate; eyes

large, gray, prominent; ocelli small, pearly, equidistant from each other and from the eyes and situated well above a line drawn through centers of eyes; clypeus obovate extending for half its length below inferior margins of clypeus, tip rounded and feebly pilose.

Pronotum black, shining, on metopidium and dorsum, faintly punctate at lateral margins, not pubescent; humeral angles large, prominent; metopidium sloping, broader than high; posterior process heavy, tricarinate, acute, extending well beyond internal angles of tegmina but not reaching tip of abdomen.

Tegmina smoky hyaline; base black, coriaceous and punctate; a broad brown fascia across center of tegmen and a brown spot on external margin before apex; veins brown; five apical and two discoidal areas.

Sides of thorax and undersurface of body black; femora black; tibiæ black at base and then shining brown for apical two-thirds; tarsi brown.

Length from front of head to tips of tegmina, 6.6 millimeters; width between tips of humeral angles, 3.5.

Type, female.

Type locality, Ripang, northern Luzon, Philippine Islands.

Described from a single specimen. Type in author's collection.

OTINOTOIDES PUBESCENS sp. nov. Plate 1, fig. 7.

Small, brown, punctate, densely pubescent with closely matted white hairs; suprahumeral horns heavy, black, extending outward and slightly upward; posterior process long, heavy, decurved, reaching almost to tips of tegmina; tegmina hyaline, base brown and punctate, veins strongly pubescent; sides of thorax white, tomentose; legs brown.

Head wider than long, light brown, densely pubescent; base arcuate, roughly sinuate; eyes large, yellowish; ocelli large, yellow, prominent, farther from each other than from the eyes and situated about on a line drawn through centers of eyes; clypeus as wide as long, trilobed, projecting for half its length below inferior margins of genæ, tip pointed.

Pronotum light brown, densely pubescent; metopidium as broad as high, nearly straight above head; humeral angles large, prominent; median carina very strongly percurrent; suprahumeral horns large, flattened dorsoventrally, about as long as the distance between their bases, projecting outward and very slightly upward, upper surfaces carinate; posterior process long,

heavy, decurved, base weakly laterally carinate, tip extending almost to tips of tegmina; scutellum strongly exposed, densely tomentose.

Tegmina hyaline; base and costal margin coriaceous, punctate, and densely pubescent; veins strong and strongly pubescent; five apical and two discoidal cells.

Sides of thorax entirely white tomentose; undersurface of abdomen densely pubescent; legs light brown; hind trochanters unarmed.

Length from front of head to tips of tegmina, 5.6 millimeters; width between tips of suprahumeral horns, 3.8.

Type, female.

Type locality, Amboina.

Described from a single specimen. Type in author's collection

MAGUVA NIGRA sp. nov. Plate 1, fig. 8.

Large, black, shining, punctate, not pubescent; suprahumeral horns long, slender, curved, sharp; posterior process sinuate with heavy conical elevation on basal dorsal margins; tegmina black with three hyaline fasciæ; undersurface black; legs dark brown.

Head much broader than long, convex, black, punctate, not pubescent; base irregularly arcuate; eyes large, black; ocelli small, amber-colored, not conspicuous, farther from each other than from the eyes and situated about on a line drawn through centers of eyes; clypeus twice as wide as long, strongly trilobed, projecting for half its length below inferior margins of genæ.

Prothorax black, shining, punctate, not pubescent; metopidium about as broad as high, sloping; humeral angles large, prominent, extending laterad farther than the eyes; median carina faintly percurrent; suprahumeral horns about as long as the distance between their bases, slender, curved, sharp, projecting upward and outward and curving slightly downward; posterior process sinuate, a heavy conical elevation at base, tip reaching to a point about halfway between internal angle and tip of tegmina; scutellum well exposed.

Tegmina black, coriaceous, opaque and punctate at base and on costal margin; internal margin from base to internal angle black but not punctate; a subquadrangular hyaline spot in middle of tegmen, separated by a black band from a transverse hyaline area behind it and this again separated by a narrow black band from a third hyaline area just before the tip; veins strong and black, not pilose; five apical and three discoidal areas.

Sides of thorax and undersurface of body black, lightly tomentose; legs dark brown.

Length from front of head to tips of tegmina, 6 millimeters; width between tips of suprahumeral horns, 4.

Type, female.

Type locality, Meranke, Dutch New Guinea.

Described from two females from the same locality. Type and paratype in author's collection.

EBHUL ELEGANS sp. nov. Plate 1, fig. 9.

Large, shining, brown, punctate, not pubescent; carinate on median dorsal line above humeral angles; no suprahumerals nor lateral carinæ; posterior process elevated above scutellum, then weakly sinuate, extending just to internal angles of tegmina; tegmina opaque, shining brown with hyaline spot before apex; sides of thorax strongly toothed; undersurface and legs brown.

Head longer than broad, strongly declivous, brown, punctate, not pubescent, roughly sculptured; base arcuate with a small nodule on each side median line; eyes large, light brown; ocelli small, brown, elevated, located very close to lateral margins, very much farther from each other than from the eyes and situated well above a line drawn through centers of eyes; clypeus longer than wide, extending for two-thirds its length below inferior margin of genæ, tip truncate.

Pronotum shining brown, finely punctate, not pubescent; metopidium broader than high, sloping; humeral angles strong, prominent; median carina strongly percurrent, produced to form a low crest on median dorsal line; no suprahumerals nor lateral carina above humeral angles; posterior process slightly elevated at base above scutellum, then weakly sinuate to tip which extends just to internal angles of tegmina; scutellum entirely exposed, longer than wide, bifid at tip.

Tegmina opaque, shining brown, punctate of basal and costal margins, a broad hyaline spot near external margin before the tip, this hyaline area crossed by two brown veins.

Sides of thorax produced to form two strong teeth on each side; legs and undersurface of body shining brown.

Length from front of head to tips of tegmina, 6 millimeters; width between tips of humeral angles, 2.5.

Type, female.

Type locality, Manorg, West Borneo.

Described from a single specimen. Type in author's collection.

TRICENTRUS PORRECTUS sp. nov. Plate 1, fig. 10.

Small, brown, punctate, pubescent; suprahumeral horns porrect, extending upward and forward; posterior process sharply carinate, acute, reaching just beyond internal angles of tegmina; tegmina hyaline, base brown and punctate, veins nodulate, a brown spot at apex; undersurface of body black; legs brown. This species seems to be very close to *T. projectus* Distant.

Head black, finely punctate, densely pubescent, black in front and brown behind; humeral angles weak, rounded; suprahumeral horns projecting upward, forward, and slightly outward, about as long as twice the distance between their bases, not extending laterad as far as the humeral angles, sharply anteriorly and posteriorly carinate, laterally compressed, tips rounded as seen from the side; scutellum broadly exposed, black at base and brown at tip, densely pilose. Posterior process strongly carinate above, tip acute and extending just beyond internal angles of tegmina.

Tegmina wrinkled, hyaline; base brown, opaque, and punctate; apical external margin narrowly brown; veins brown and strongly nodulate; five apical and two discoidal areas.

Sides of thorax black and pilose; undersurface of body black; trochanters black; femora black with brown tips; tibiæ and tarsi luteus.

Length from front of head to tips of tegmina, 1.7 millimeters; width between tips of suprahumerals, 1.7.

Type, male.

Type locality, Davao, Mindanao, Philippine Islands (*Francisco Rivera*), March, 1927.

Described from a single specimen. Type in author's collection.

TRICENTRUS FORTICORNIS sp. nov. Plate 1, fig. 11; Plate 2, fig. 12.

Large, black, punctate, pubescent; suprahumerals strong, heavy, sharp, extending upward and outward; posterior process slender, sharp, extending beyond internal angles of tegmina; tegmina bronze-hyaline, with outer margins darker; large white spot on abdomen shining through base of tegmina; undersurface black; legs brown.

Head subquadrate, black, finely punctate; densely pubescent with long golden hairs; base regularly arcuate; eyes large, brown; ocelli large, brown, equidistant from each other and from the eyes and situated slightly above a line drawn through centers of eyes; clypeus longer than wide, extending for more than half its length below inferior margins of genæ, tip rounded and pilose.

Pronotum black, roughly punctate, pubescent with long golden hairs; humeral angles strong, prominent, blunt; median carina strongly percurrent; metopidium convex, about as wide as high; suprahumeral horns strong, heavy, extending outward and upward with tips curving backward, tricarinate, somewhat compressed dorsoventrally, more than twice as long as the distance between their bases, upper surface ridged at tip, tips acute; posterior process long, slender, tricarinate, acute, tip extending beyond internal angles of tegmina and just about reaching end of abdomen; scutellum well exposed.

Tegmina bronze-hyaline; base black, opaque, and punctate; external margin from base to tip dark brown; large white spot on abdomen shining through tegmen just behind opaque area; five apical and two discoidal cells.

Sides of thorax black and pubsecent; undersurface of body black; legs ferruginous brown.

Length from front of head to tips of tegmina, 7.2 millimeters; width between tips of suprahumerals, 4.4.

Type, male.

Described from a pair from Imugan, Nueva Vizcaya Province, Luzon, and a pair from Trinidad, northern Luzon, Philippine Islands, and one female labeled only "Philippine Islands." Collector, E. H. Taylor.

Type and two paratypes in author's collection; allotype and one paratype in collection of Philippine Bureau of Science.

TRICENTRUS BAKERI sp. nov. Plate 1, fig. 13; Plate 2, fig. 14.

Small, black, pubescent, punctate, suprahumerals projecting outward and slightly upward; posterior process reaching just beyond internal angles of tegmina; tegmina bronze-hyaline with bases black; undersurface black; legs dark brown; no tomentose patches.

Head subquadrate, finely punctate, densely pubescent; base feebly arcuate and sinuate; eyes light brown; ocelli pearly, slightly elevated, equidistant from each other and from the eyes and situated above a line drawn through centers of eyes; clypeus longer than wide, extending for half its length below inferior margins of genæ, tip rounded and pilose.

Pronotum black, finely punctate, densely pubescent with short golden hairs; metopidium wider than high, nearly straight; humeral angles blunt, prominent, triangular; median carina very faintly percurrent; suprahumeral horns heavy, tricarinate, extending outward and upward, about as long as the distance be-

tween their bases, tips sharp and recurved, compressed dorsoventrally, upper surface weakly carinate; posterior process heavy, carinate, acute, extending just beyond internal angles of tegmina; scutellum broadly exposed at sides.

Tegmina bronze-hyaline, wrinkled; base black, opaque, and punctate; five apical and two discoidal cells.

Sides of thorax black and pubescent; undersurface of body black; legs dark brown.

Length from front of head to tips of tegmina, 5.8 millimeters; width between tips of suprahumerals, 3.5.

Type, female.

Type locality, Sandakan, Borneo (*C. F. Baker*).

Described from four females and two males all from the same locality. Type, allotype, and three paratypes in author's collection; one paratype in collection of Philippine Bureau of Science.

TRICENTRUS ATTENUICORNIS sp. nov. Plate 1, fig. 15; Plate 2, fig. 16.

Golden brown, punctate, pubescent, suprahumeral horns short, very slender and sharp, extending outward and upward; posterior process long, carinate, sinuate, sharp, extending well beyond internal angles of tegmina; tegmina smoky hyaline, wrinkled, narrowly brown at base; undersurface and legs brown.

Head subquadrate, brown, finely punctate, densely pubescent; base feebly arcuate and sinuate; eyes large, light brown; ocelli large, amber-colored, equidistant from each other and from the eyes and situated slightly above a line drawn through centers of eyes; clypeus longer than wide, extending for half its length below inferior margins of genæ, tip rounded and pilose.

Pronotum golden brown, finely punctate, densely pubescent; humeral angles large, prominent, triangular; metopidium broader than high, convex; suprahumeral horns short, slender, sharp, not as long as the distance between their bases, extending outward, upward, and backward, slightly compressed dorsoventrally, carinate above, tips acuminate; posterior process sharply carinate, heavy at base, slender for apical half, weakly sinuate, tip acuminate, tricarinate, reaching well beyond internal angles of tegmina, scutellum well exposed.

Tegmina smoky-hyaline, wrinkled; base narrowly brown, opaque and punctate; external margin faintly clouded with brown near apex; veins strong and brown; five apical and two discoidal cells.

Sides of prothorax dark brown, densely pubescent; undersurface dark brown; legs light brown.

Length from front of head to tips of tegmina, 6 millimeters; width between tips of suprahumerals, 3.6.

Type, female.

Type locality, Sandakan, Borneo (*C. F. Baker*).

Described from two females. Type and paratype in author's collection.

TRICENTRUS ALBESCENS sp. nov. Plate 1, fig. 17; Plate 2, fig. 18.

The single specimen described below, bearing Baker's duplicate No. 9826, has been standing for several years in our collection under the label *T. allebens* Distant and was so reported to Professor Baker. We have always been suspicious, however, of our determination and recently sent the specimen to Mr. W. E. China, of the British Museum, who kindly compared it with the type and reports that it is not Distant's species. We are therefore describing it as new. The writer is not aware at this time of the location of all of Baker's material, but his specimens bearing the above number should be referred to this species. This is a small black form with strongly recurved suprahumerals and a large white tomentose spot in the sides of the prothorax.

Head subquadrate, black, finely punctate, densely pubescent; base feebly sinuate; eyes brown; ocelli conspicuous, brown, farther from each other than from the eyes and situated above a line drawn through centers of eyes; clypeus twice as long as wide, extending for half its length below inferior margins of genæ, tip rounded and pilose.

Pronotum black, finely punctate, finally and densely pubescent; metopidium broader than high, a glabrous spot above each eye; median carina weakly percurrent; humeral angles prominent, sharp; suprahumeral horns heavy, curved, extending outward and upward and curving backward, about as long as the distance between their bases, compressed dorsoventrally, tips acute, carinate above; posterior process straight; tricarinate, reaching beyond the internal angles of the tegmina; scutellum broadly exposed.

Tegmina hyaline, wrinkled, base broadly black, opaque, punctate, and pubescent; external margin from base to tip dark brown; five apical and two discoidal cells.

Sides of thorax densely white tomentose; undersurface of body black; femora dark brown; tibiæ and tarsi ferruginous.

Length from front of head to tips of tegmina, 4.6 millimeters; width between tips of suprahumerals, 3.

Type, female.

Type locality, Sandakan, Borneo (*C. F. Baker*).

Described from a single specimen. Type in author's collection.

TRICENTRUS FULGIDUS sp. nov. Plate 2, figs. 19 and 20.

Brown, shining, polished, not punctate, not pubescent; eyes brilliant red; shining white spot showing through bases of tegmina; suprahumerals short, blunt, extending directly outward; posterior process extending beyond internal angles of tegmina; undersurface brown.

Head subquadrate, broader than long, brown, shining, not punctate, not pubescent; base nearly straight; eyes bright red; ocelli pearly, inconspicuous, farther from each other than from the eyes and situated above a line drawn through centers of eyes; clypeus extending for half its length below inferior margin of genæ, tip rounded.

Pronotum dark brown, smooth, polished, not punctate, not pubescent; metopidium broader than high; humeral angles weak, blunt; median carina obsolete over metopidium; suprahumeral horns short, blunt, extending directly outward, not as long as one-fourth the distance between their bases; scutellum well exposed; posterior process very heavy at base, slender for posterior half, tip acuminate and extending well beyond internal angles of tegmina, almost reaching tip of abdomen.

Tegmina smoky, hyaline; base dark brown, opaque, and punctate; a broad white spot showing through tegmina just behind opaque area; veins very strong, brown; five apical and two discoidal areas.

Sides of thorax and undersurface of abdomen dark brown, almost black, very faintly pubescent; legs uniformly brown.

Length from front of head to tips of tegmina, 5.7 millimeters; width between tips of suprahumeral horns, 3.3.

Type, female.

Type locality, Pontianak, Borneo.

Described from a single specimen. Type in author's collection.

TRICENTRUS PAPUAENSIS sp. nov. Plate 2, figs. 21 and 22.

Small, black, punctate, pubescent; suprahumerals short, sharp, extending outward and backward; posterior process heavy, tricarinate, sharp, reaching beyond internal angles of tegmina; tegmina hyaline with base black; undersurface of body black; legs ferruginous brown.

Head subquadrate, wider than long, black, finely punctate, densely pubescent; base arcuate; eyes large, brown; ocelli large

but inconspicuous, translucent white, equidistant from each other and from the eyes and situated above a line drawn through centers of eyes; clypeus longer than wide, deflexed, extending for half its length below inferior margins of genæ, tip rounded and pilose.

Pronotum black, finely punctate, densely pubescent, with very short hairs; metopidium broader than high, sloping; median carina faintly percurrent; humeral angles weak, triangular, blunt; suprahumeral horns short, sharp, almost as long as half the distance between their bases, extending almost directly outward and curving strongly backward; scutellum widely exposed; posterior process heavy, tricarinate, base thick, apex attenuate, tip sharp and extending well beyond internal angles of tegmina, just about reaching tip of abdomen.

Tegmina hyaline, wrinkled; base black, opaque, and punctate; veins heavy, yellowish; five apical and two discoidal areas.

Sides of thorax and undersurface of abdomen black and pubescent; femora brown with apical ends ferruginous; tibiæ, tarsi, and claws ferruginous.

Length from front of head to tips of tegmina, 5.2 millimeters; width between tips of suprahumeral horns, 3.

Type, male.

Type locality, Laloki, Papua.

Described from a single specimen. Type in author's collection. We sent this specimen to Mr. W. E. China, of the British Museum, for comparison with the type of Walker's *T. congestus,* which it seemed to resemble, and he reported it as "near" this species but not identical.

TRICENTRUS FERRUGINOSUS sp. nov. Plate 2, figs. 23 and 24.

Large, ferruginous, punctate, pubescent; suprahumeral horns long, sharp, extending outward and upward, posterior process slightly curved, sharp, extending beyond internal angles of tegmina; tegmina fuscous-hyaline, wrinkled, base ferrunginous; undersurface and legs ferruginous.

Head wider than long, ferruginous, finely punctate, densely pubescent; base arcuate and slightly sinuate; eyes large, ferruginous; ocelli small, ferruginous, equidistant from each other and from the eyes and situated above a line drawn through centers of eyes; clypeus longer than wide, deflexed, extending for half its length below inferior margins of genæ; tip rounded and pilose.

Pronotum ferruginous, finely punctate, densely pubescent; metopidium wider than high, sloping; median carina percurrent; humeral angles heavy, triangular, blunt; suprahumeral horns about as long as the distance between their bases, extending outward and upward, upper surface carinate, tips sharp; scutellum well exposed; posterior process long, slender, slightly curving upward, tricarinate, tip sharp and dark brown, extending beyond internal angles of tegmina, but not reaching tip of abdomen.

Tegmina fuscous-hyaline, much wrinkled; base ferruginous opaque and punctate; veins heavy and brown; five apical and two discoidal areas.

Sides of thorax ferruginous and pubescent; abdomen dark ferruginous; legs uniformly ferruginous.

Length from front of head to tips of tegmina, 6.5 millimeters; width between tips of suprahumeral horns, 4.6.

Type, female.

Type locality, Penang Island (*C. F. Baker*).

Described from a single specimen. Type in author's collection.

TRICENTRUS ALTIDORSUS sp. nov. Plate 2, figs. 25 and 26.

Small, brown, punctate, pubescent, suprahumerals broad and rounded; posterior process distinctly elevated; tegmina hyaline with brown bases; undersurface dark brown; legs brown.

Head subquadrangular, broader than long, dark brown, finely punctate, densely pubescent, convex; base regularly arcuate; eyes light brown; ocelli large, light yellow-brown, translucent, equidistant from each other and from the eyes and situated on a line drawn through centers of eyes; clypeus about as broad as long, extending for half its length below inferior margins of genæ, pilose, tip rounded.

Pronotum golden brown, finely punctate, densely pubescent; metopidium as broad as high, convex, darker above each eye; humeral angles triangular, prominent; suprahumeral horns half as long as the distance between their bases, stout, blunt, extending upward and outward, flattened dorsoventrally, tips rounded; scutellum well exposed; posterior process heavy, short, blunt, carinate, the dorsal margin strongly elevated, tip extending just beyond internal angles of tegmina.

Tegmina wrinkled hyaline; base coriaceous brown and punctate; tip pointed; veins indistinct; five apical and two discoidal areas.

Undersurface of body dark brown; legs golden brown; tarsi luteus brown.

Length from front of head to tips of tegmina, 4 millimeters; width between tips of suprahumeral horns, 2.8.

Type, female.

Type locality, Penang Island (*C. F. Baker*).

Described from a single specimen now in author's collection.

TRICENTRUS NIGROFRONTIS sp. nov. Plate 2, figs. 27 and 28.

Jet black with brown tegmina, punctate, pubescent; suprahumeral short, sharp, triangular, extending outward and upward; posterior process sharp, extending just to internal angles of tegmina; tegmina brown and subcoriaceous with bases black; undersurface black; legs dark brown.

Head black, punctate, pubescent; base sinuate and arcuate; eyes dark brown; ocelli amber-colored, translucent, conspicuous, equidistant from each other and from the eyes and situated about on a line drawn through center of eyes; clypeus deflexed, longer than broad, extending for half its length below inferior margins of genæ, tip rounded and pilose.

Pronotum black, finely punctate, sparingly pubescent; metopidium convex, broader than high; median carina percurrent; humeral angles large, prominent, triangular; suprahumeral horns as long as half the distance between their bases, triquerate, sharp, extending outward and very slightly upward; scutellum well exposed; posterior process strong, carinate, sharp, extending just to internal angles of tegmina; dorsal margin slightly arcuate.

Tegmina brown, wrinkled, translucent, somewhat coriaceous; base opaque, black, and punctate; veins prominent, brown; five apical and two discoidal cells.

Undersurface of body black; sides of thorax pubescent; legs very dark brown; tarsi ferruginous brown.

Length from front of head to tips of tegmina, 5.6 millimeters; width between tips of suprahumeral horns, 3.2.

Type, female.

Type locality, Penang Island (*C. F. Baker*).

Described from a single specimen. Type in author's collection.

TRICENTRUS SULUENSIS sp. nov. Plate 2, figs. 29 and 30.

Black, punctate, pubescent; tegmina smoky hyaline with bases black; suprahumerals short, sharp, extending upward and backward; posterior process straight, sharp, extending just beyond internal angles of tegmina; undersurface black; legs ferruginous.

Head subquadrangular, broader than high, black, punctate, densely pubescent with golden hairs; base arcuate, slightly sin-

uate; eyes brown; ocelli large, brown, conspicuous, equidistant from each other and from the eyes and situated above a line drawn through centers of eyes; clypeus feebly trilobed, extending for half its length below inferior margins of genæ, tip rounded, densely pilose.

Pronotum black, finely punctate, densely pubescent; metopidium lightly convex, broader than high, a black spot above each eye; median carina distinct behind horns, obsolete over metopidium; suprahumerals as long as the distance between their bases, extending outward, upward, and curving backward; humeral angles broad, heavy, blunt; scutellum well exposed; posterior process strong, straight, sharp, tricarinate, extending slightly beyond internal angles of tegmina, but not reaching tip of abdomen.

Tegmina smoky hyaline, wrinkled; base opaque, black, and punctate; veins strong, brown, and at apical costal region distinctly pilose; five apical and two discoidal cells; terminal limbus narrow.

Undersurface of body black; sides of thorax densely pubescent; legs ferruginous.

Length from front of head to tips of tegmina, 6.5 millimeters; width between tips of suprahumeral horns, 3.8.

Type, female.

Type locality, Tawitawi, Sulu, Philippine Islands.

Described from a single specimen. Type in author's collection.

TRICENTRUS BRUNNEICORNIS sp. nov. Plate 2, figs. 31 and 32.

Small, yellow with suprahumerals and end of posterior process dark brown; punctate, pubescent; suprahumerals long, sharp, extending outward and upward; posterior process extending just beyond internal angles of tegmina; undersurface brown; legs yellow-brown.

Head dark brown, deflexed, punctate, densely pubescent; base nearly straight; eyes yellow-brown; ocelli large, yellow, prominent, elevated, equidistant from each other and from the eyes and situated about on a line drawn through centers of eyes; clypeus brown, pubescent, extending for half its length below inferior margins of genæ, tip rounded and pilose.

Pronotum dark yellow with a spot above each eye; most of the suprahumerals and the apical half of the posterior process dark brown; metopidium broader than high, convex; median carina faintly percurrent; humeral angles large, prominent, triangular; suprahumeral horns as long as the distance between

their bases, sharp, brown, flattened dorsoventrally, extending outward and upward and curving backward; posterior process slender, straight, acute, tricarinate, reaching just beyond internal angles of tegmina; scutellum well exposed.

Tegmina hyaline and somewhat wrinkled; base brown, opaque, and punctate; veins prominent and brown; terminal limbus broad; five apical and two discoidal cells.

Undersurface of body dark brown; femora luteus brown; tibiæ and tarsi luteus.

Length from front of head to tips of tegmina, 5.4 millimeters; width between tips of suprahumeral horns, 3.

Type, male.

Type locality, Basilan, Philippine Islands.

Described from a single specimen. Type in author's collection.

TRICENTRUS PUBESCENS sp. nov. Plate 2, figs. 33 and 34.

Large, brown, punctate, densely pubescent; suprahumerals short, sharp, extending upward and outward; posterior process slender, sharp, extending beyond internal angles of tegmina; tegmina hyaline with base brown; undersurface brown; legs ferruginous.

Head subquadrangular, wider than long, brown, punctate, pubescent; base arcuate, feebly sinuate; eyes brown; ocelli small, pearly, inconspicuous, equidistant from each other and from the eyes and situated about on a line drawn through centers of eyes; clypeus longer than wide, extending for half its length below inferior margins of genæ.

Pronotum brown, punctate, pubescent; metopidium broader than high with a dark spot above each eye; median carina percurrent; humeral angles strong, prominent, triangular; suprahumeral horns slender, sharp, as long as the distance between their bases, extending outward, slightly upward, and curving backward, faintly carinate on upper surface; scutellum well exposed; posterior process slender, sharp, slightly decurved, tricarinate, extending well beyond internal angles of tegmina but not reaching tip of abdomen.

Tegmina wrinkled hyaline; base brown, opaque, and punctate; veins heavy and brown; apical limbus broad; five apical and two discoidal cells.

Undersurface of body dark brown; legs and tarsi ferruginous.

Length from front of head to tips of tegmina, 6.8 millimeters; width between tips of suprahumerals, 4.2.

Type, female.

Type locality, Catbalogan, Samar, Philippine Islands.

Described from a single specimen. Type in author's collection.

GARGARA ORNATA sp. nov.

Small, black, punctate, pubescent; posterior process sinuate, just reaching internal angles of tegmina; tegmina dark brown, decorated with many white spots; undersurface and legs black.

Head subovate, longer than wide, black, punctate, pubescent, convex; base weakly sinuate; eyes large, glassy; ocelli very small, transparent, inconspicuous, twice as far from each other as from the eyes and situated above a line drawn through centers of eyes; clypeus spatulate, extending for half its length below inferior margins of genæ, tip broadly rounded.

Pronotum black, finely punctate, finely pubescent; metopidium sloping, wider than high; median carina strong on posterior process but obsolete on metopidium; humeral angles large, prominent, triangular; no suprahumerals; scutellum broadly exposed at sides; posterior process short, sinuate, blunt, extending just to the internal angles of the tegmina.

Tegmina opaque, brown, thickly decorated with white spots; veins indistinct; five apical and two discoidal cells; tip rounded; apical limbus narrow.

Undersurface of body entirely black; legs and feet black.

Length from front of head to tips of tegmina, 2.8 millimeters; width between humeral angles, 1.6.

Type, male.

Type locality, Borneo.

Described from a single specimen. Type in author's collection.

GARGARA BRUNNEIDORSATA sp. nov.

Small, black, punctate, not pubescent; median dorsal area broadly brown; posterior process short, heavy, blunt, decurved, reaching just to internal angles of tegmina; tegmina with basal half hyaline and apical half broadly brown; undersurface black; legs brown.

Head subquadrangular, nearly twice as broad as high, convex, finely punctate, not pubescent; base sinuate; eyes brown; ocelli small, opaque white, prominent, twice as far from each other as from the eyes and situated well above a line drawn through centers of eyes; clypeus triangular, extending for one-fourth its length beyond inferior margins of genæ, tip broadly rounded, slightly pubescent.

Pronotum black, finely punctate, not pubescent; median carina sharp on posterior process but not extending over metopidium;

median dorsal line broadly brown; metopidium sloping, wider than high; humeral angles prominent, blunt; posterior process short, blunt, decurved, extending just to internal angles of tegmina; scutellum narrowly exposed.

Tegmina with basal half hyaline and apical half opaque with large brown spot covering almost all of distal portion; veins indistinct; five apical and two discoidal cells; tip rounded; apical limbus narrow; costal marginal vein feebly punctate.

Undersurface of body black; femora dark brown except apices which are ferruginous; tibiæ light brown; tarsi luteus-brown.

Length from front of head to tips of tegmina, 3.6 millimeters; width between humeral angles, 1.8.

Type, female.

Type locality, Pekalongan, Java.

Described from a single specimen. Type in author's collection.

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ILLUSTRATIONS

PLATES 1 AND 2

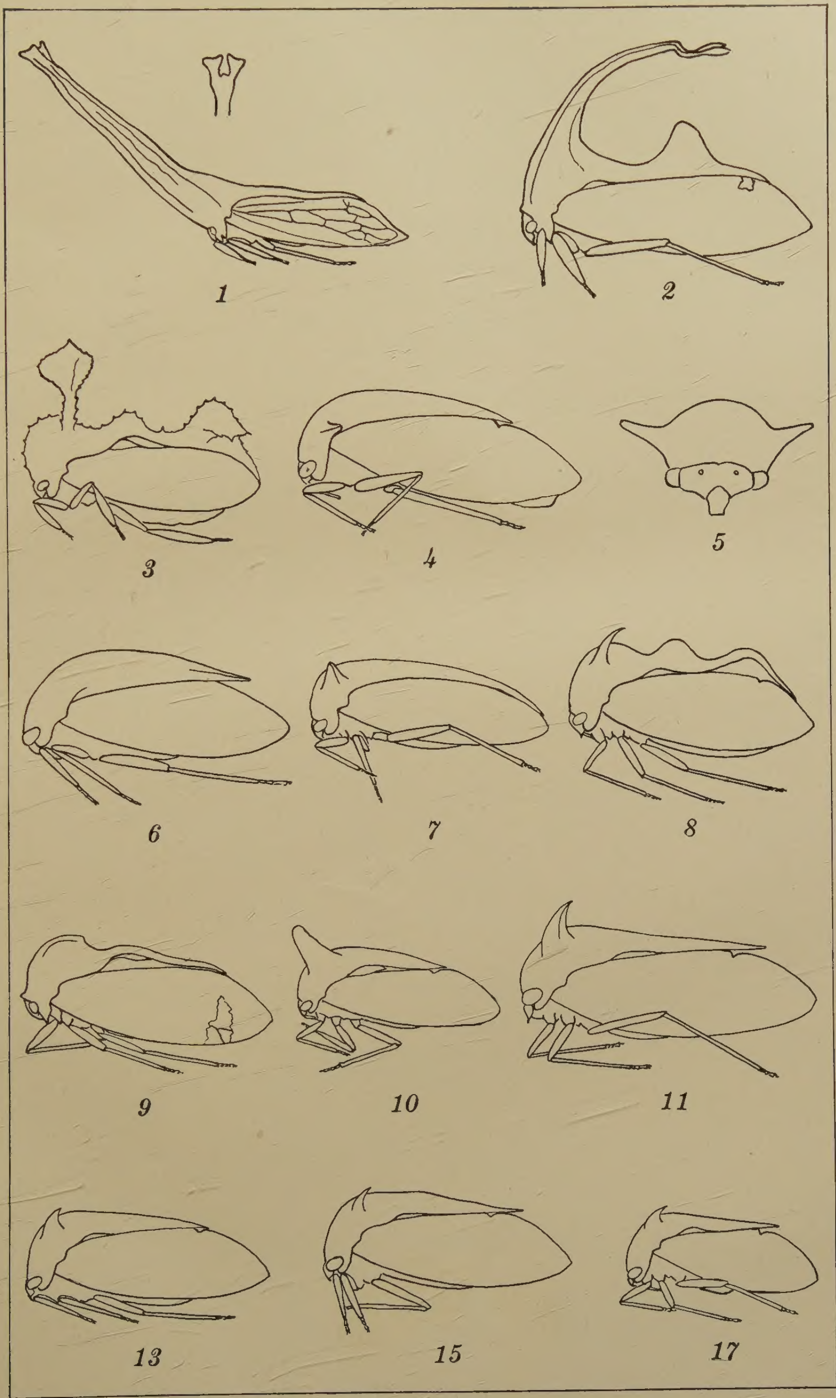

PLATE 1.

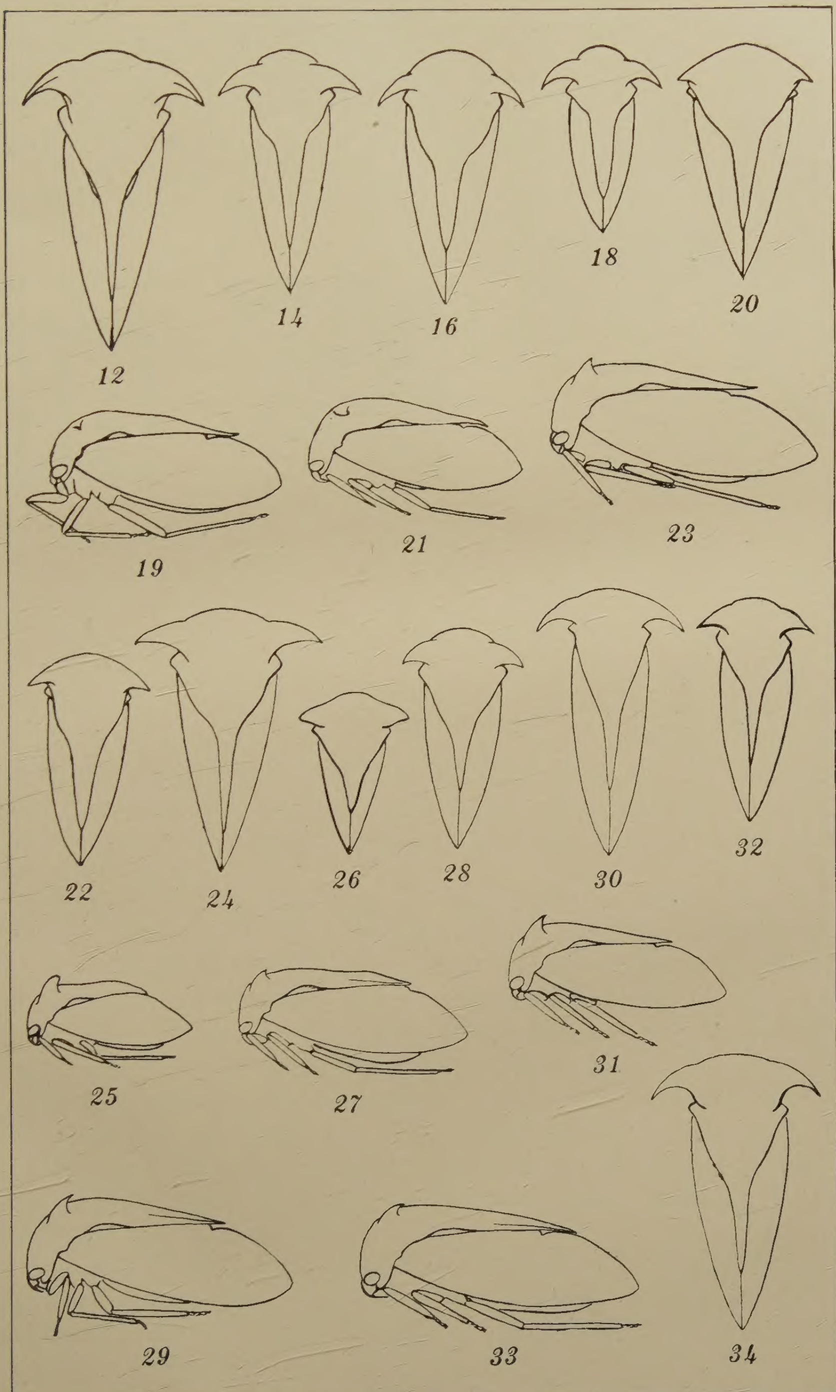

PLATE 2.